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# Western Wind and Solar Integration Study: April TRC meeting – Transmission builds



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**Debbie Lew**



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# Transmission expansion

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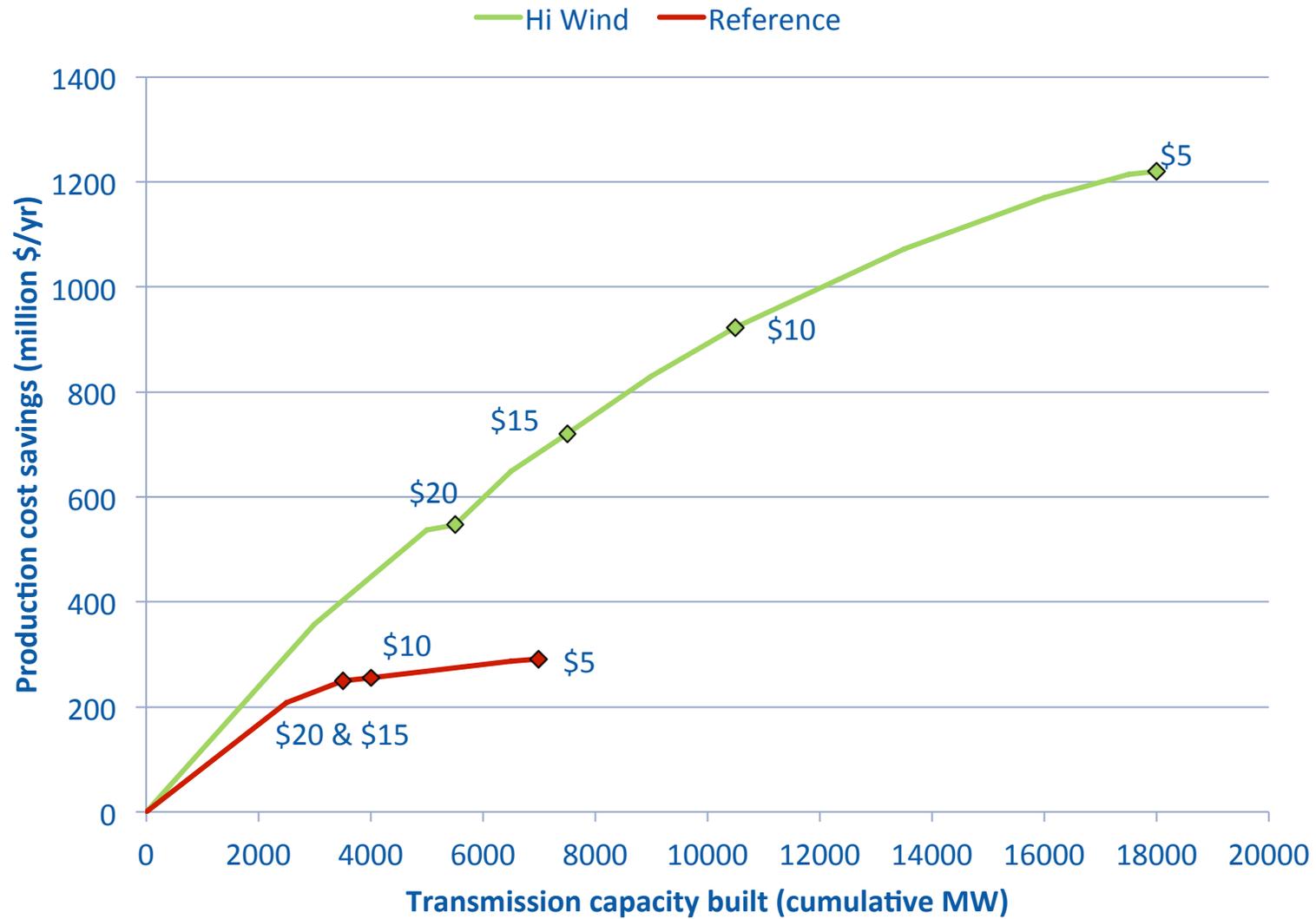
- Goal is to produce reasonable scenarios to be able to gain insights into grid operation
- 4 scenarios get 4 different transmission buildouts
  - High wind (25% wind / 8% solar)
  - High solar (8% wind / 25% solar)
  - High mix (16.5% wind / 16.5% solar)
  - Reference case (~TEPPC 2020, 8% wind / 3% solar)
- Generator buildout based on ReEDS modeling, which considers resource quality, loads, and transmission cost
- Assuming some knowledge of future builds prior to transmission decisions
- Only U.S. loads count towards percentages
- No transmission builds allowed to/from Canada and Mexico

# Transmission expansion technique

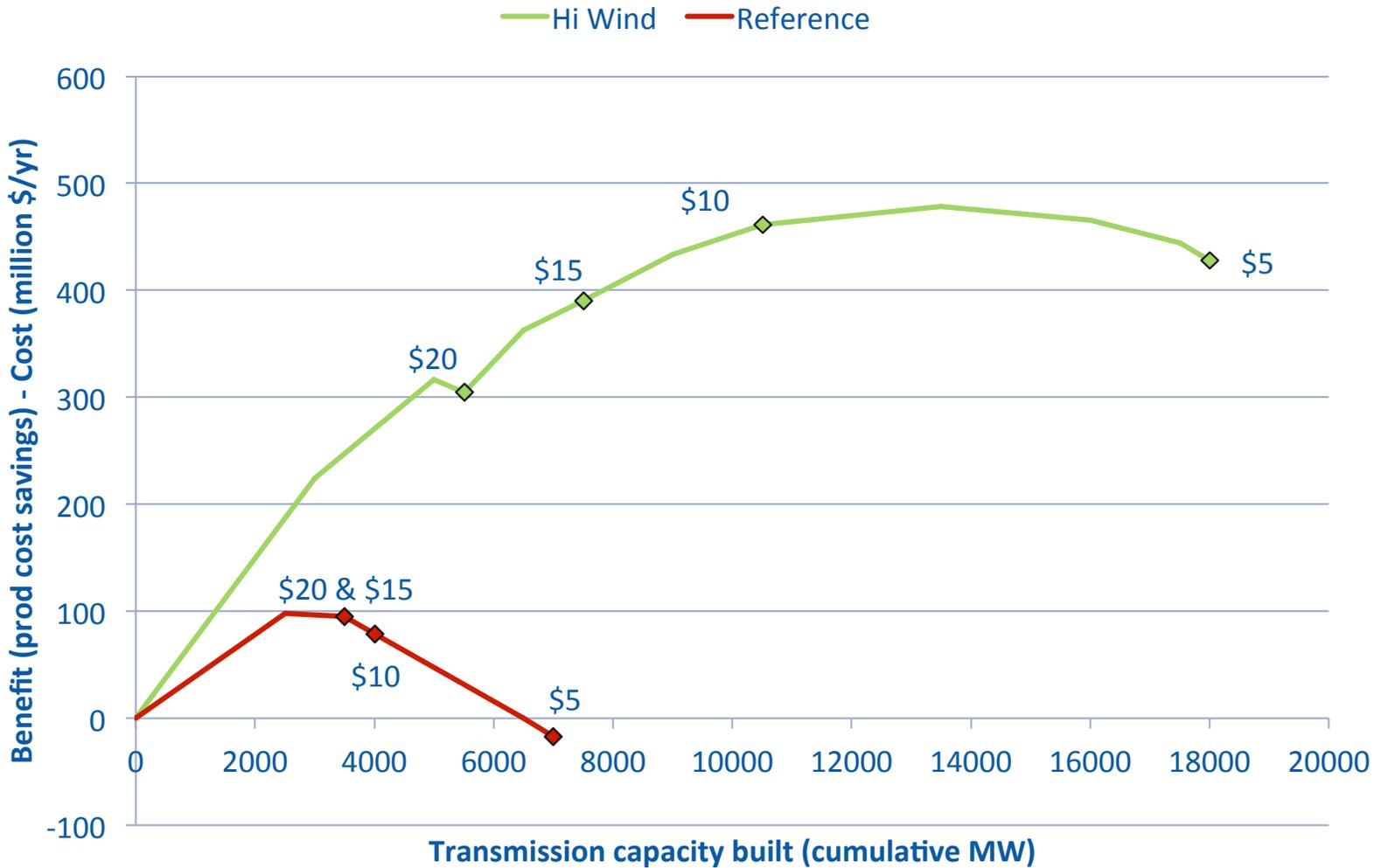
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- Assume both existing and new transmission is used optimally
- Run case in PLEXOS for full year
- Build 500 MW along interfaces with “high” shadow price
  - Test cutoffs of \$5-\$20/MW per hour
  - $\$1600/\text{MW-mi} * 0.11/\text{yr (FCR)} * 250 \text{ miles} * 1/8760 \text{ yr/hr} = \$5/\text{MW per hour}$
- Continue iterating until no more lines built
- Changes since Feb meeting
  - Alberta and Mexico are now self-supplying
  - New (2010 – 2020) interface capacity added
  - Gas prices updated
    - \$4.80 Henry Hub price
    - This will be our assumption for all core scenarios
  - Several other minor database fixes

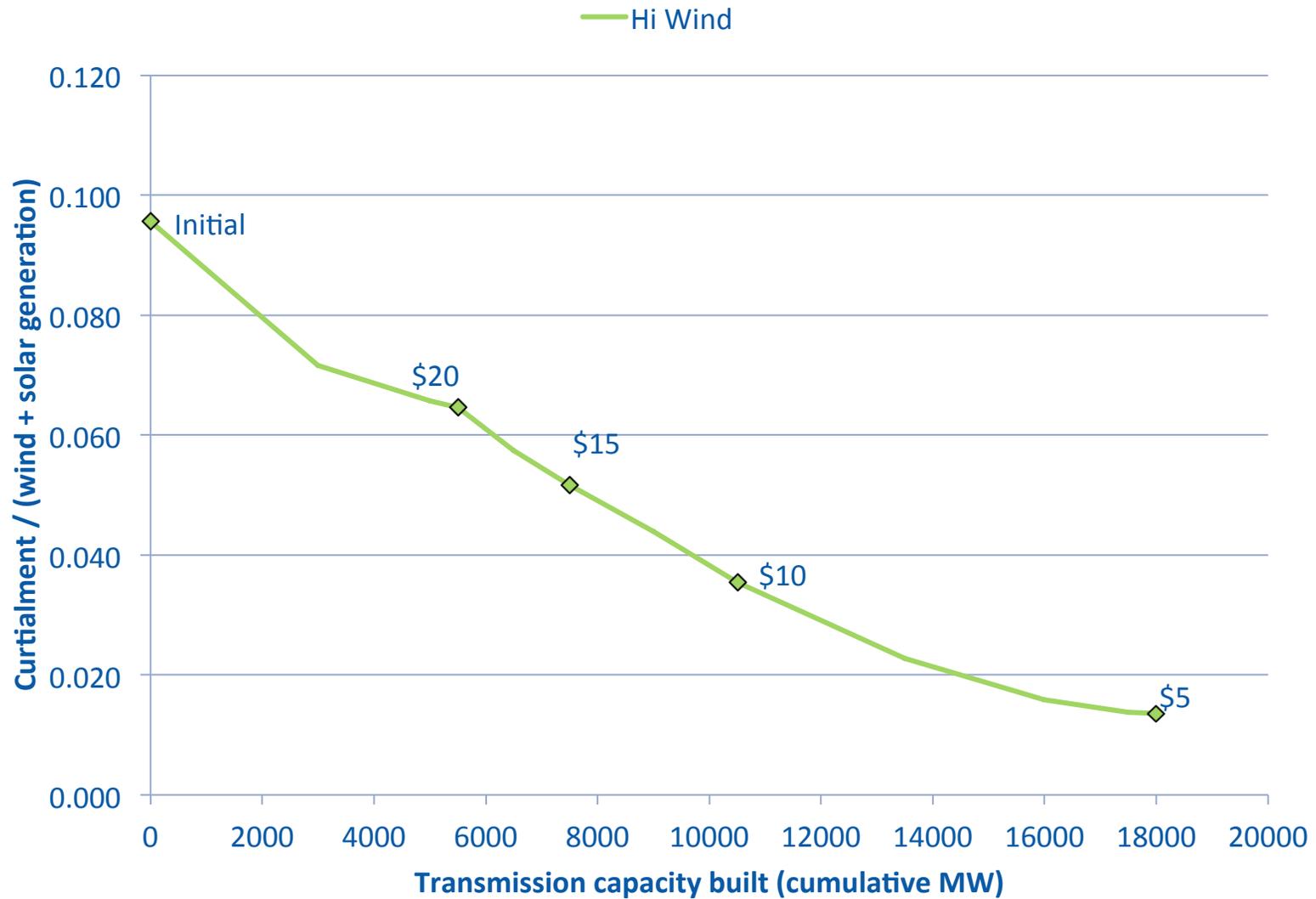
# Production cost savings vs MW built



# (Benefit-Cost) vs MW built



# Curtailment vs MW built



# Transmission buildout statistics – High wind

			Initial	\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff
A	Cumulative additional trans capacity (MW)		0	5500	7500	10500	18000
B	Cumulative trans annualized cost (million \$/yr)		\$ 0	\$ 242	\$ 330	\$ 462	\$ 792
C	Production cost (billion \$/yr)		\$ 11.8	\$ 11.3	\$ 11.1	\$ 10.9	\$ 10.6
D	Cumulative prod cost savings (million \$/yr)	$C(\text{initial})-C$		\$ 546	\$ 721	\$ 923	\$ 1,220
E	Average benefit/cost ratio	$D/B$		2.26	2.18	2.00	1.54
F	Incremental benefit/cost ratio	$\Delta D/\Delta B$		2.26	1.98	1.54	0.90
G	Curtailed (TWh)		24.8	16.7	13.4	9.2	3.5
H	Curtailed fraction	$G/(\text{potential wind} + \text{solar})$	0.096	0.065	0.052	0.035	0.014
I	Trans cost per MWh curtailed savings (\$/MWh)	$B/(G(\text{initial})-G)$		\$ 30.1	\$ 29.0	\$ 29.7	\$ 37.3

# Transmission buildout statistics – Reference

			Initial	\$20/15 cutoff	\$10 cutoff	\$5 cutoff
A	Cumulative additional trans capacity (MW)		0	3500	4000	7000
B	Cumulative trans annualized cost (million \$/yr)		0	\$ 154	\$ 176	\$ 308
C	Production cost (billion \$/yr)		\$ 15.5	\$ 15.2	\$ 15.2	\$ 15.2
D	Cumulative prod cost savings (million \$/yr)	$C(\text{initial})-C$	0	\$ 249	\$ 255	\$ 291
E	Average benefit/cost ratio	$D/B$	0	1.62	1.45	0.94
F	Incremental benefit/cost ratio	$\Delta D/\Delta B$		1.62	0.27	0.27
G	Curtailed (TWh)		1.7	0.3	0.2	0.1
H	Curtailed fraction	$G/(\text{potential wind + solar})$	0.019	0.003	0.002	0.001
I	Trans cost per MWh curtailed savings (\$/MWh)	$B/(G(\text{initial})-G)$		\$ 112	\$ 122	\$ 193



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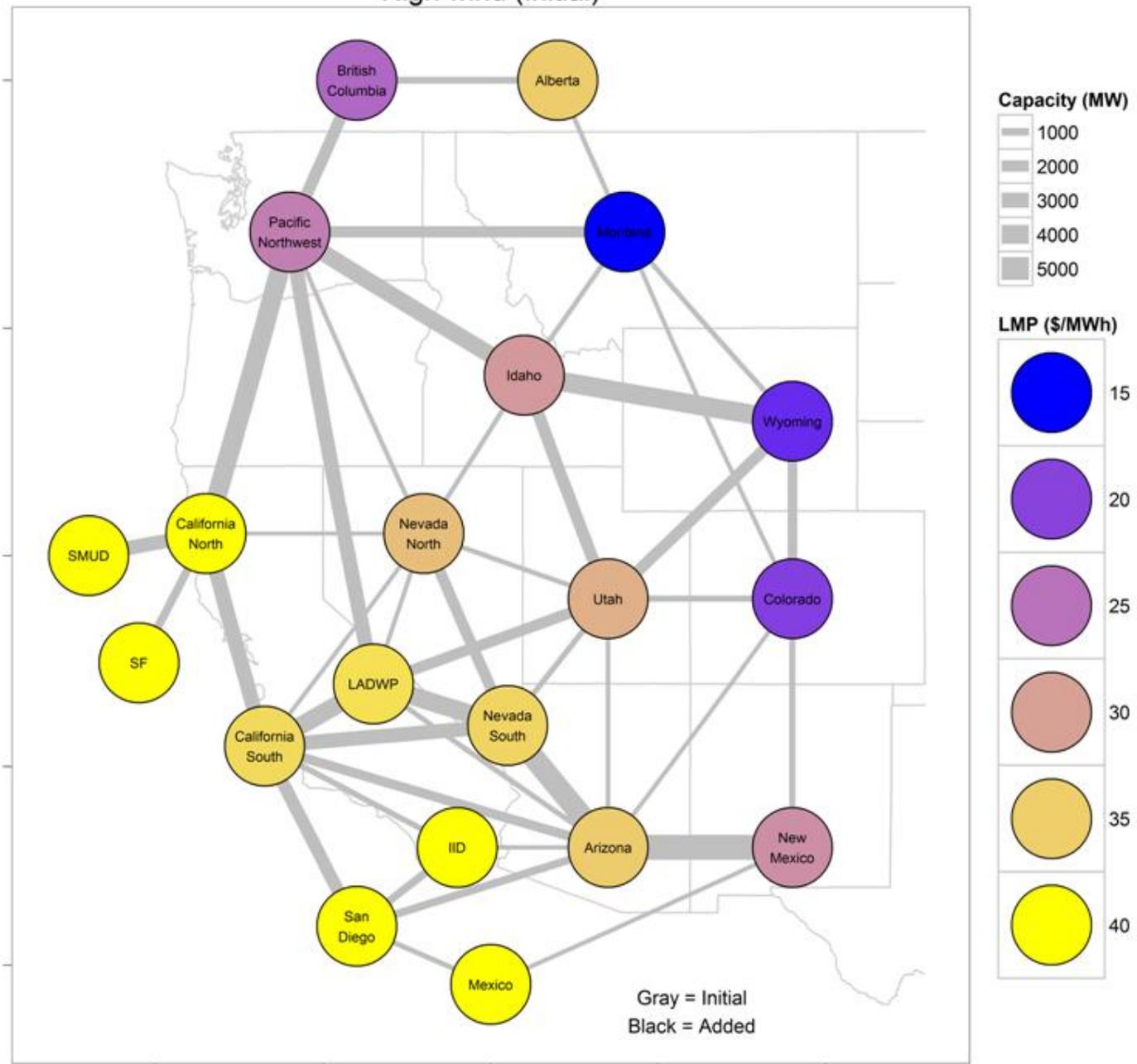
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**Base Case**

**High wind scenario**

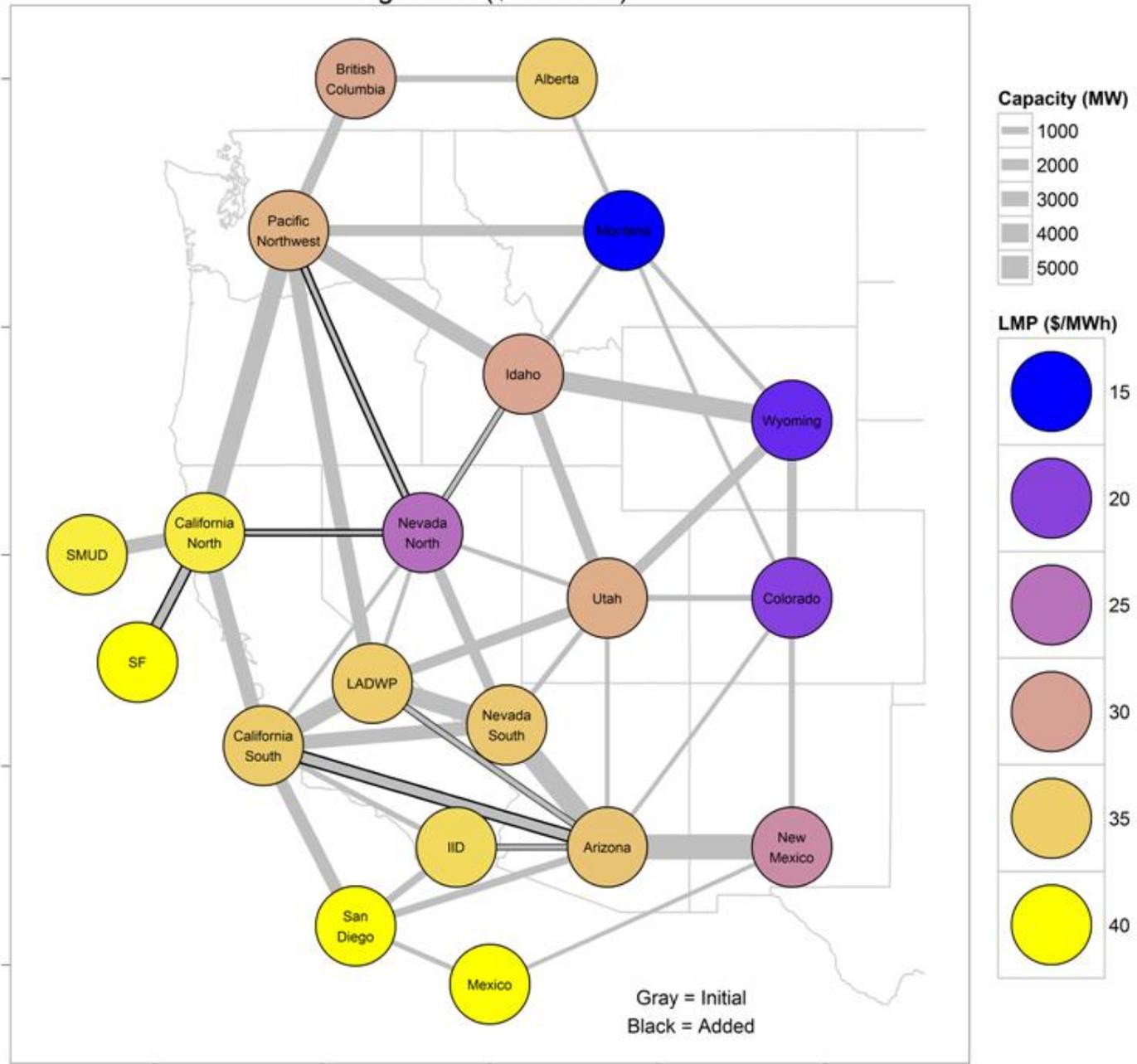


### High wind (Initial)



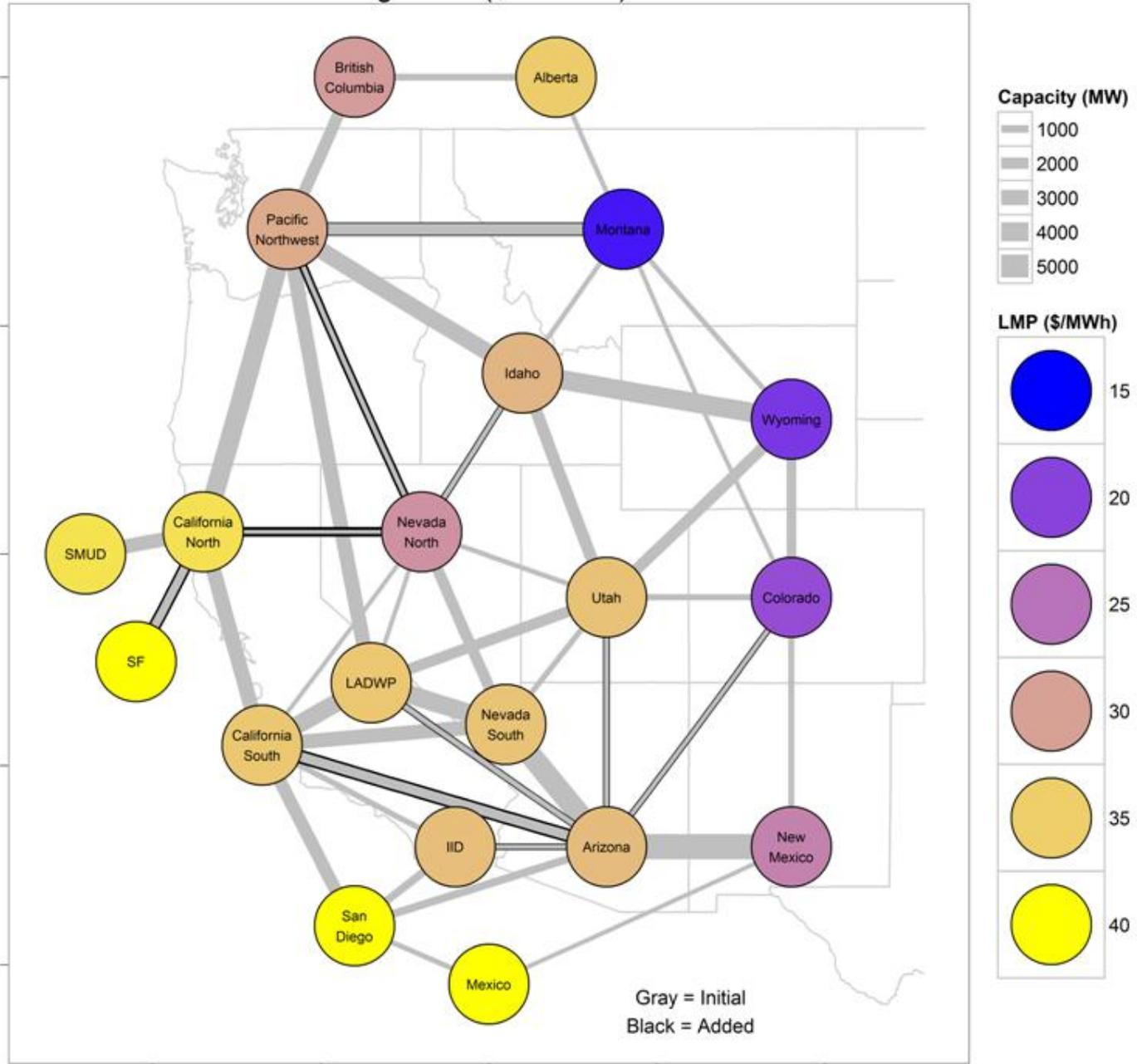


### High wind (\$20 cutoff)



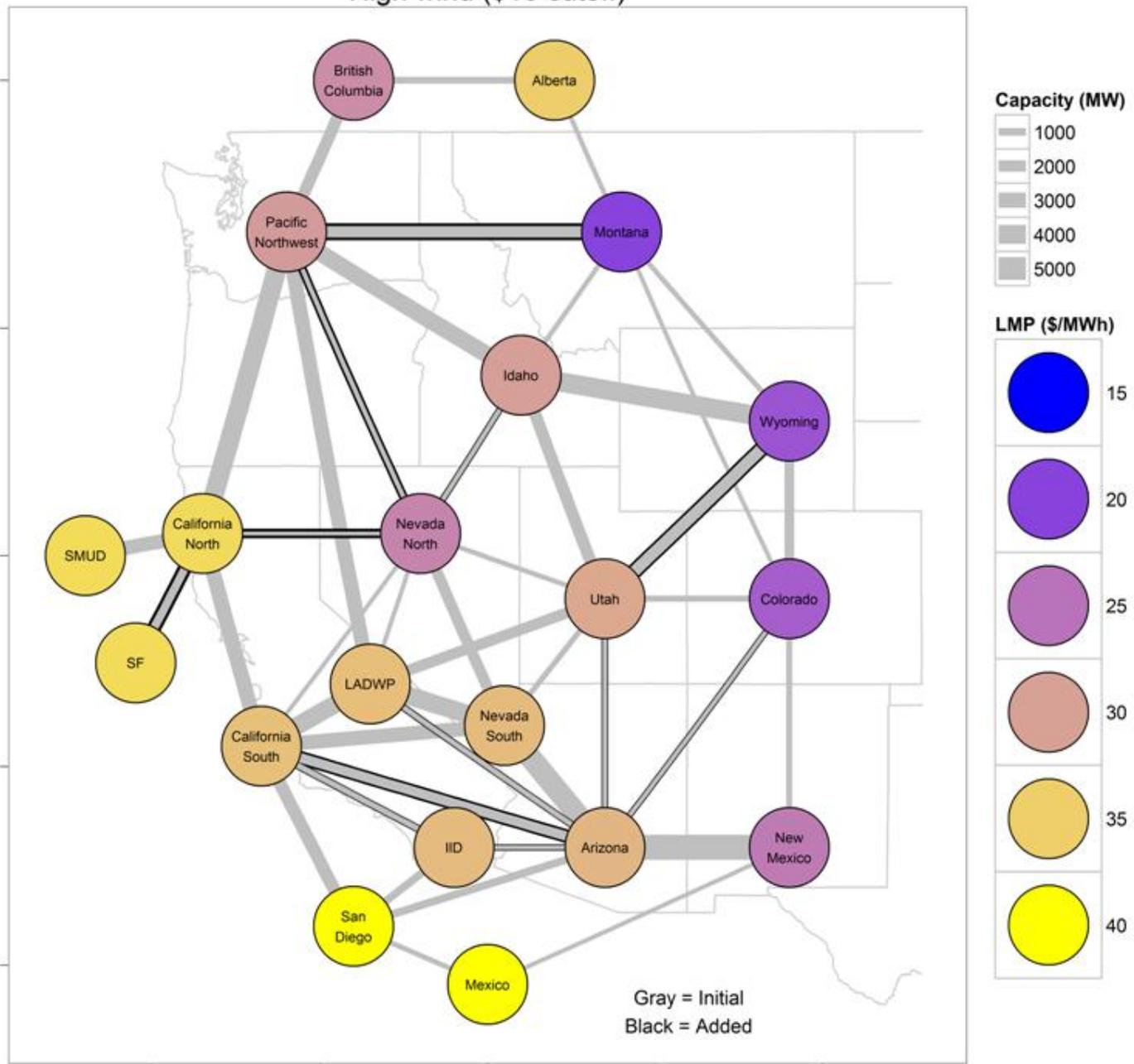


### High wind (\$15 cutoff)



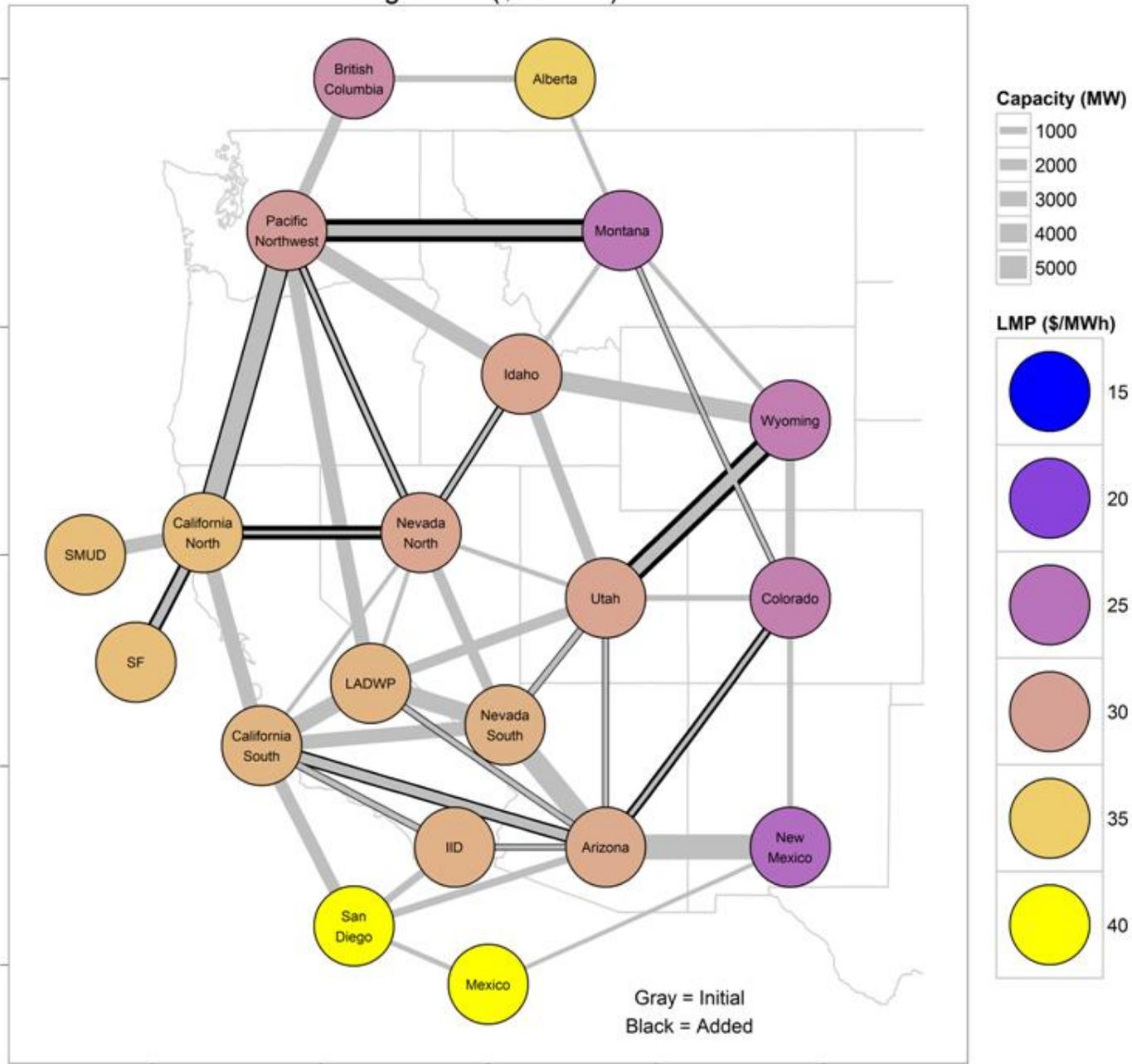


### High wind (\$10 cutoff)





### High wind (\$5 cutoff)





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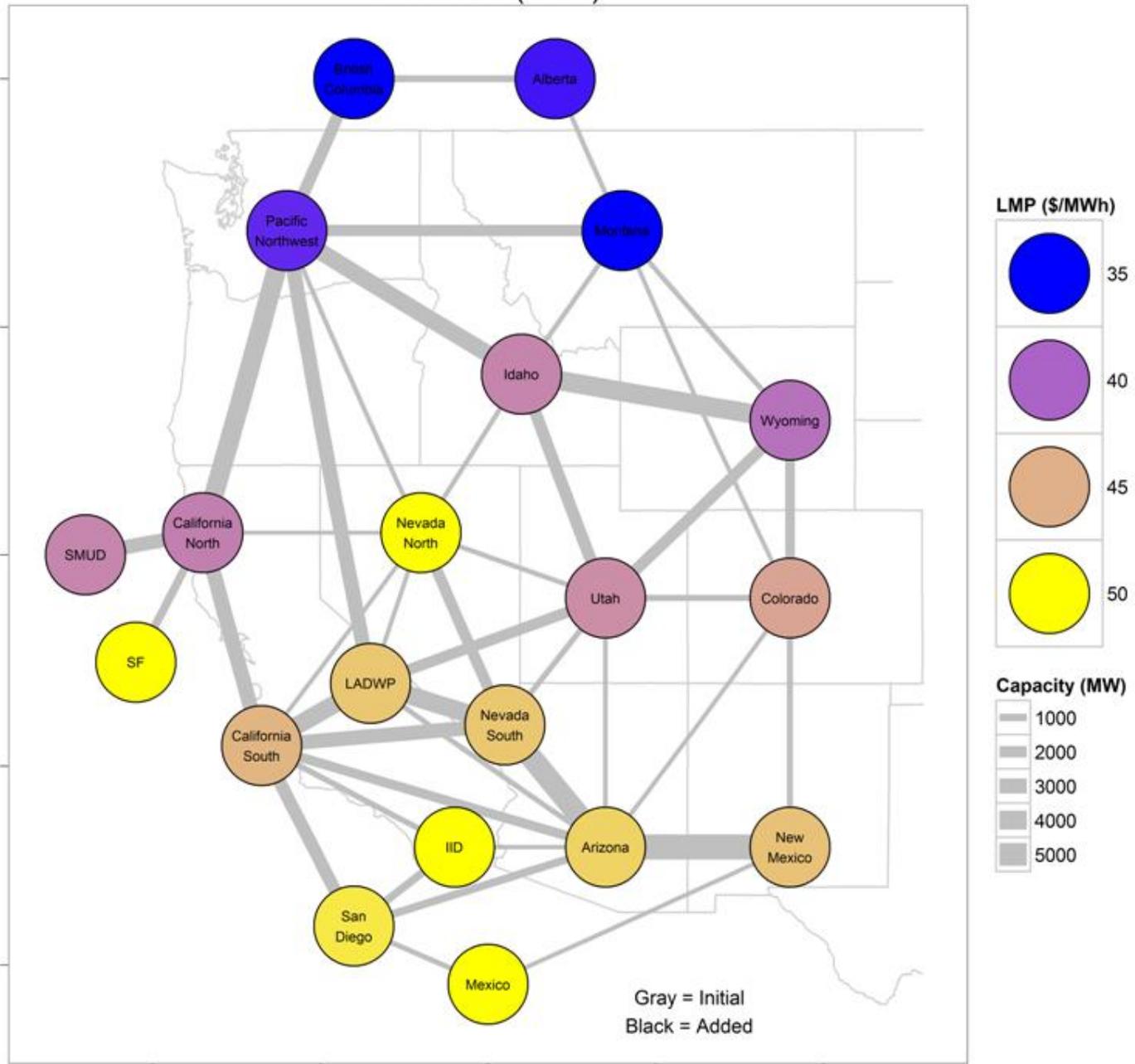
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**Base Case**

**Reference scenario**

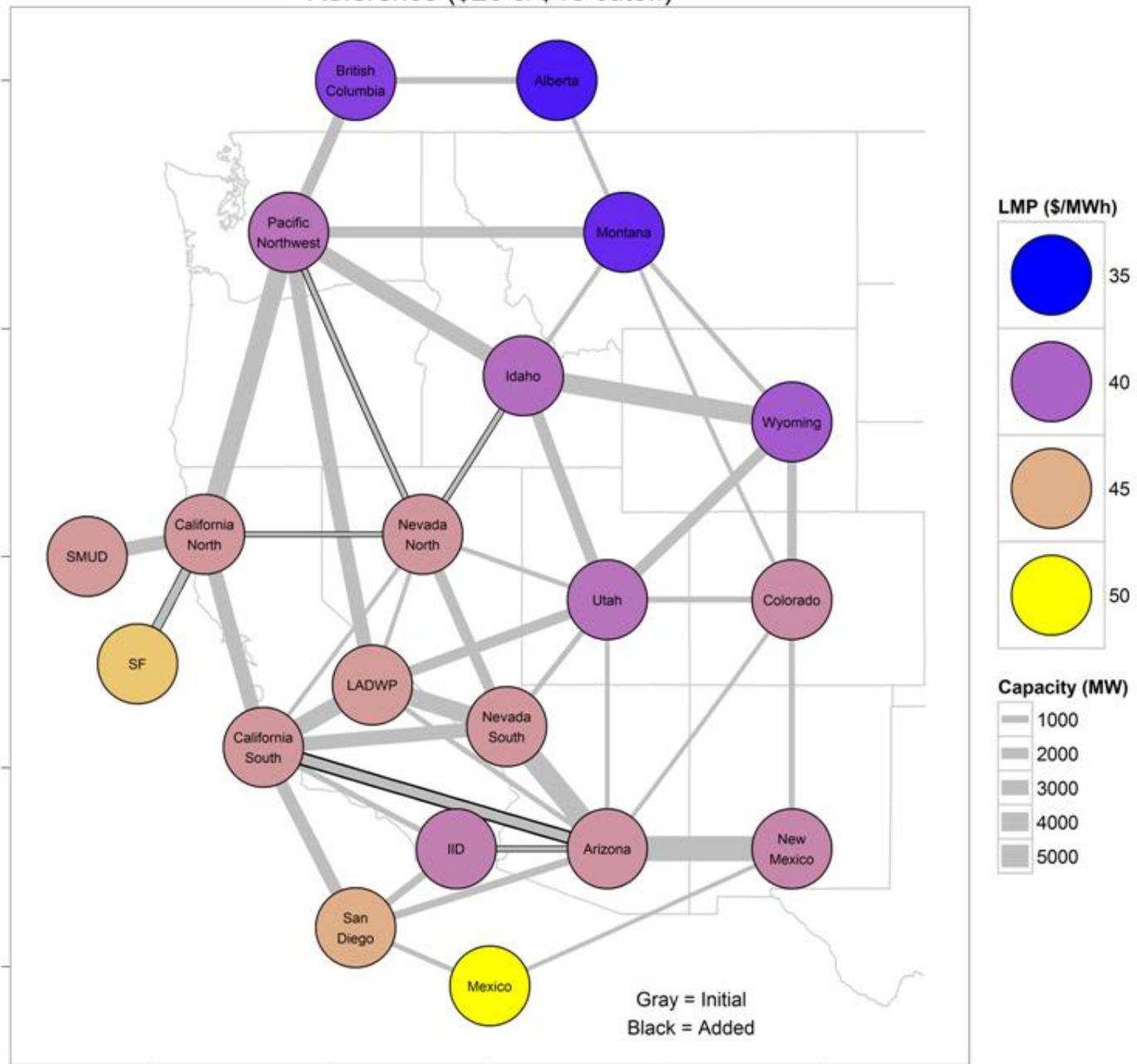


### Reference (Initial)



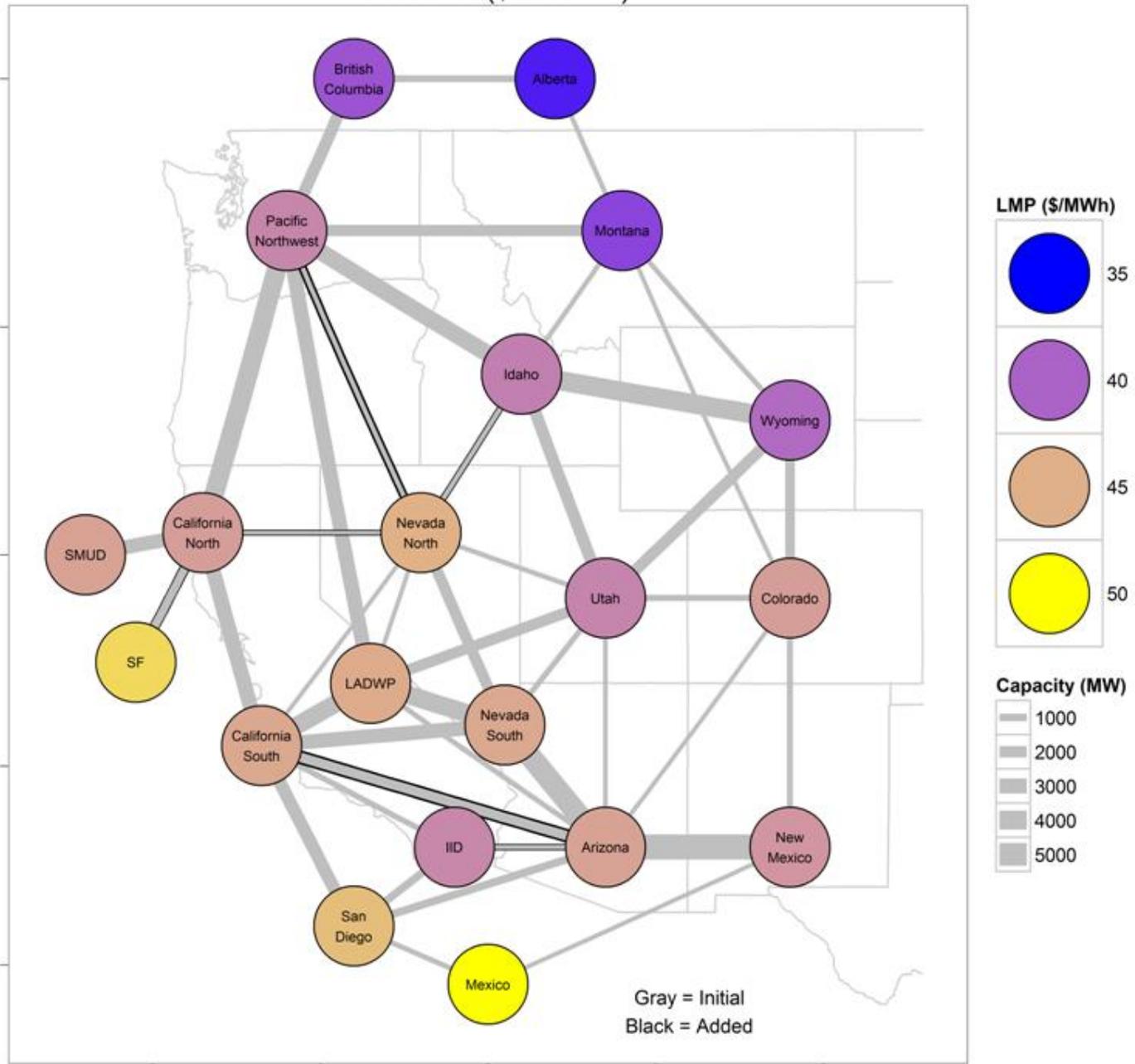


### Reference (\$20 & \$15 cutoff)



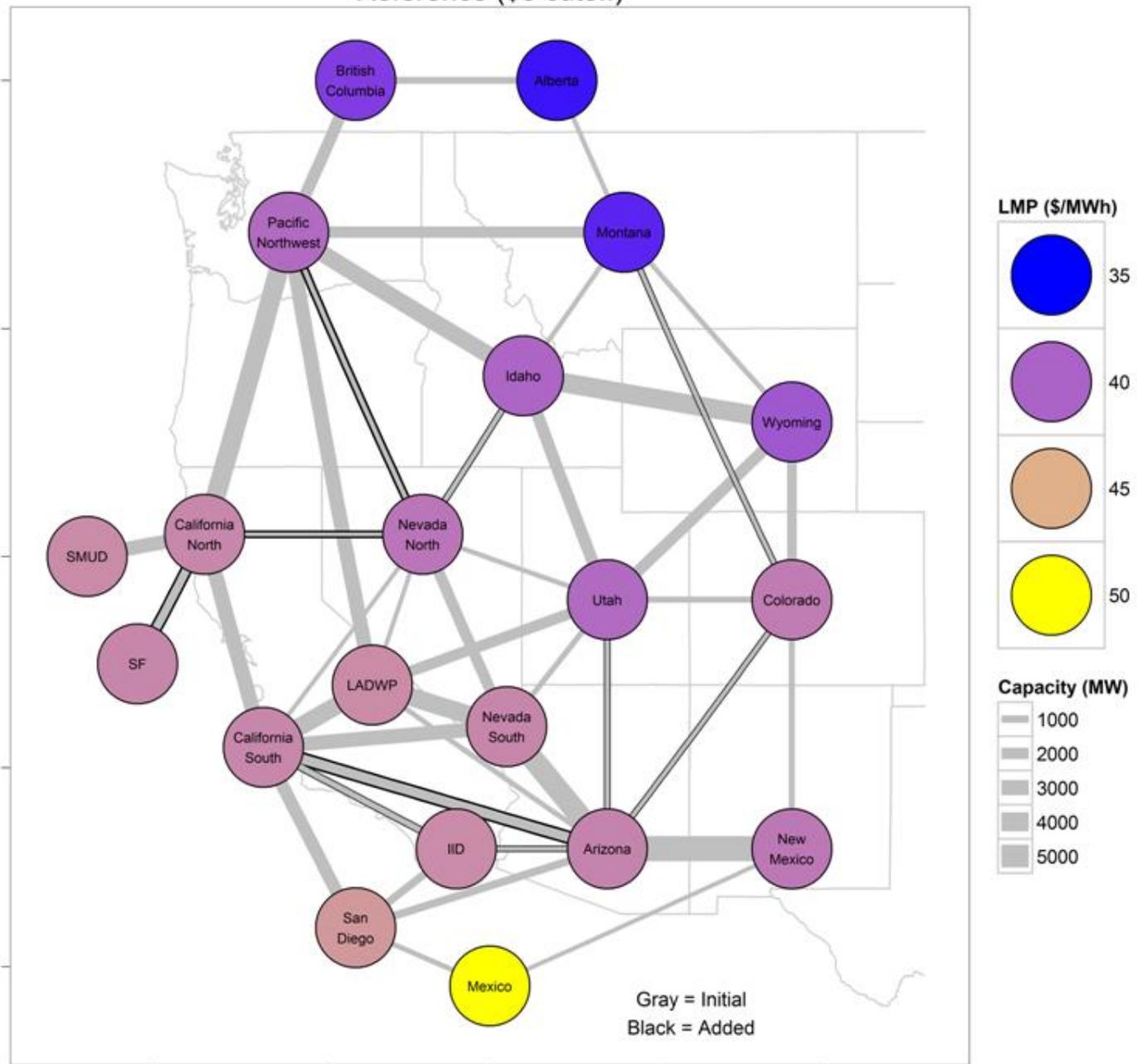


### Reference (\$10 cutoff)

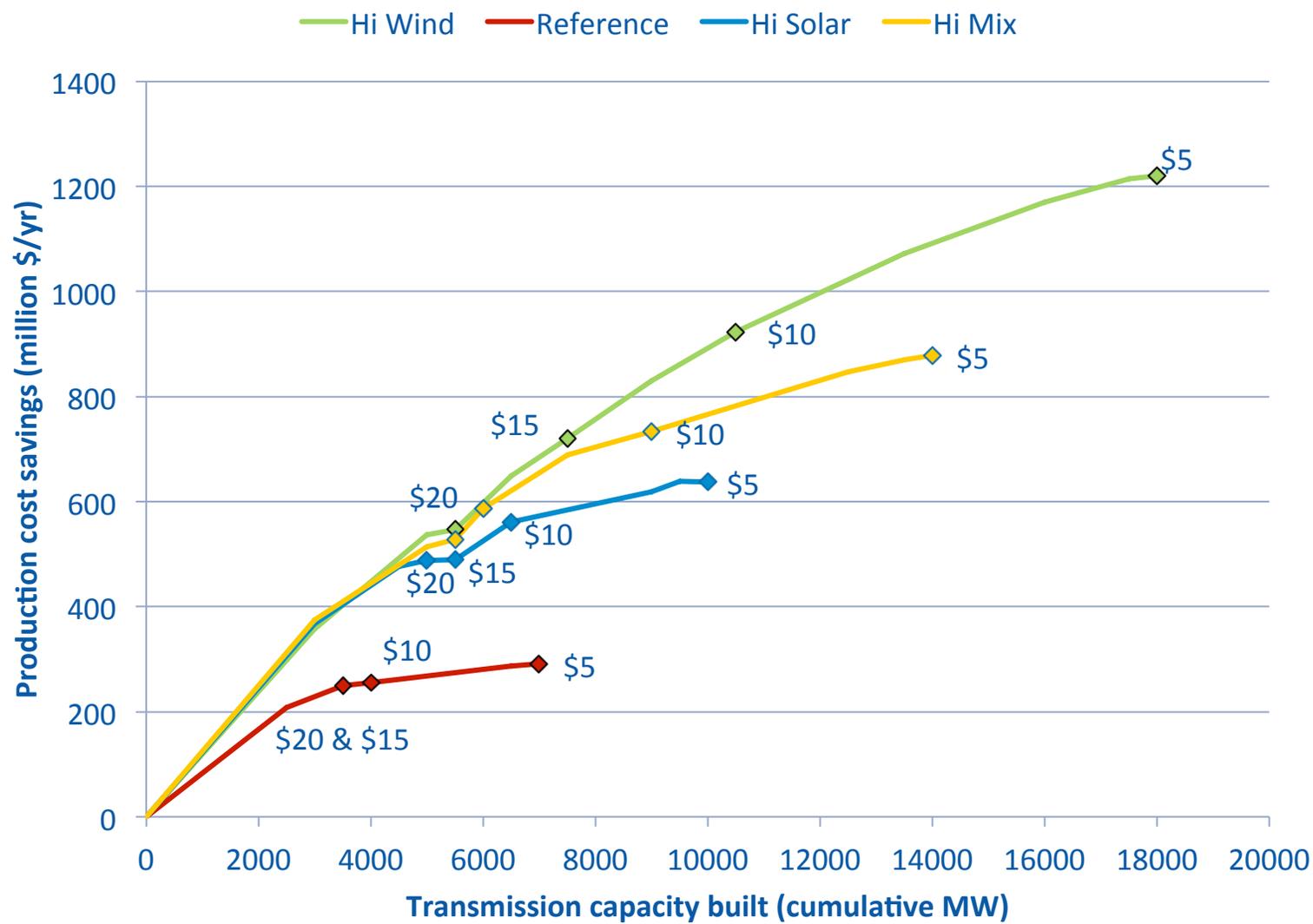




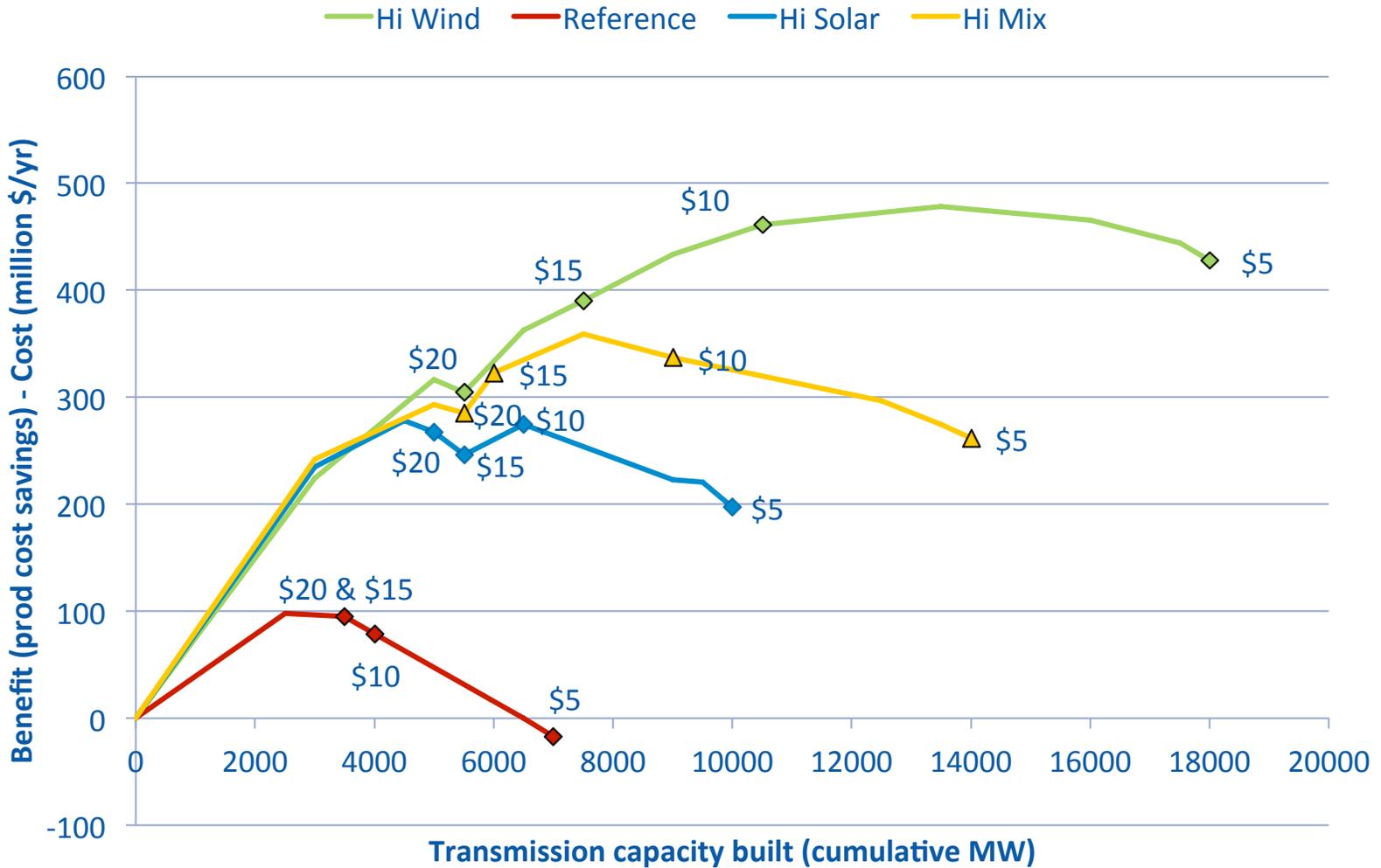
### Reference (\$5 cutoff)



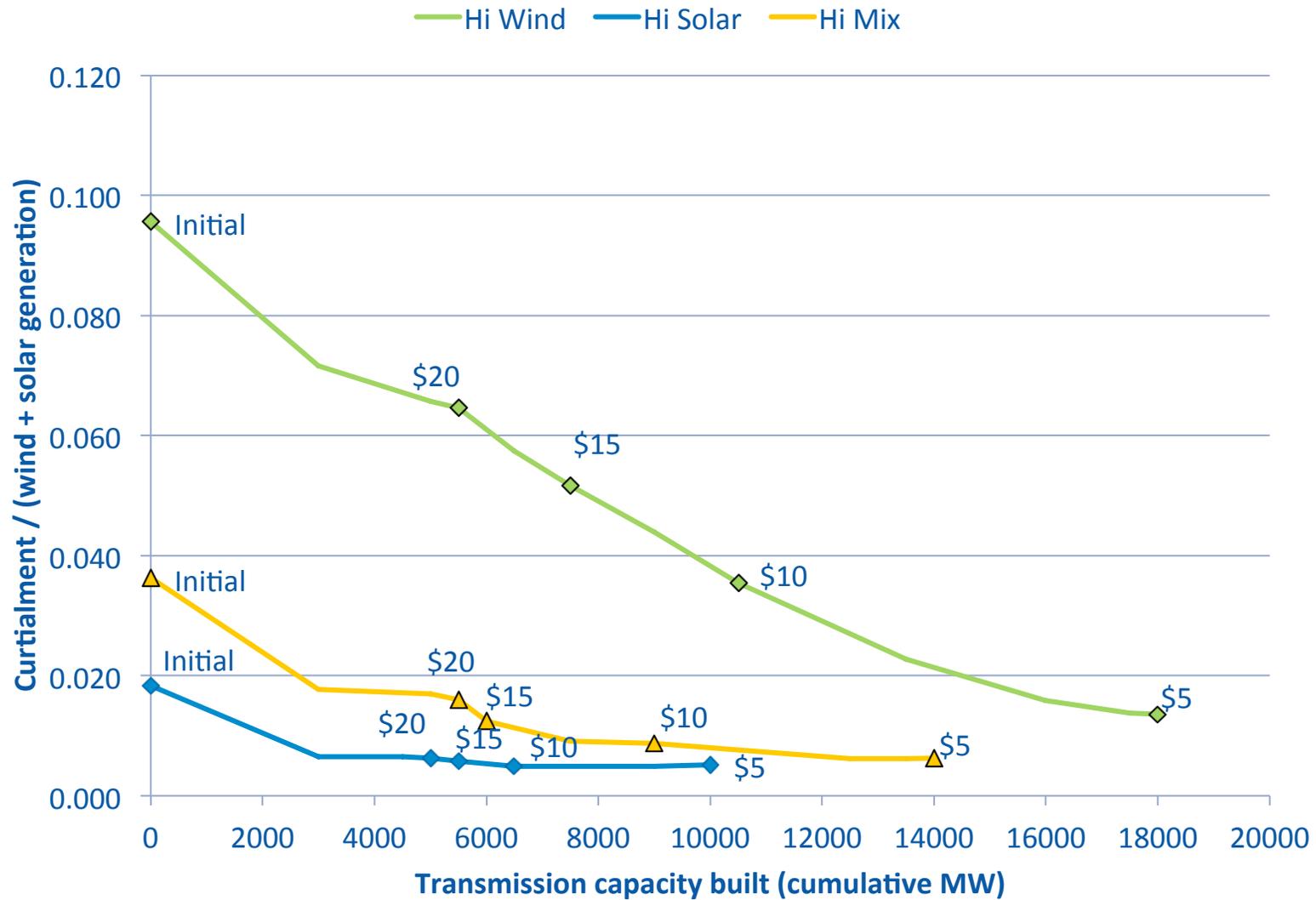
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# (Benefit-Cost) vs MW built



# Curtailment vs MW built



# Transmission buildout statistics – High wind

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I	Trans cost per MWh curtailed savings (\$/MWh)	$B/(G(\text{initial})-G)$		\$ 112	\$ 122	\$ 193

# Transmission buildout statistics – High solar

			Initial	\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff
A	Cumulative additional trans capacity (MW)		0	5000	5500	6500	10000
B	Cumulative trans annualized cost (million \$/yr)		0	\$ 220	\$ 242	\$ 286	\$ 440
C	Production cost (billion \$/yr)		\$ 11.5	\$ 11.0	\$ 11.0	\$ 10.9	\$ 10.9
D	Cumulative prod cost savings (million \$/yr)	$C(\text{initial})-C$		\$ 487	\$ 489	\$ 561	\$ 638
E	Average benefit/cost ratio	$D/B$		2.22	2.02	1.96	1.45
F	Incremental benefit/cost ratio	$\Delta D/\Delta B$		2.22	0.06	1.65	0.50
G	Curtailed (TWh)		4.7	1.6	1.5	1.3	1.3
H	Curtailed fraction	$G/(\text{potential wind} + \text{solar})$	0.018	0.006	0.006	0.005	0.005
I	Trans cost per MWh curtailed savings (\$/MWh)	$B/(G(\text{initial})-G)$		\$ 70.3	\$ 74.7	\$ 82.6	\$ 129.5

# Transmission buildout statistics – High mix

			Initial	\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff
A	Cumulative additional trans capacity (MW)		0	5500	6000	9000	14000
B	Cumulative trans annualized cost (million \$/yr)		0	\$ 242	\$ 264	\$ 396	\$ 616
C	Production cost (billion \$/yr)		\$ 11.4	\$ 10.8	\$ 10.8	\$ 10.6	\$ 10.5
D	Cumulative prod cost savings (million \$/yr)	$C(\text{initial})-C$		\$ 527	\$ 587	\$ 733	\$ 878
E	Average benefit/cost ratio	$D/B$		2.18	2.22	1.85	1.42
F	Incremental benefit/cost ratio	$\Delta D/\Delta B$		2.18	2.71	1.11	0.66
G	Curtailed (TWh)		9.4	4.1	3.2	2.3	1.6
H	Curtailed fraction	$G/(\text{potential wind} + \text{solar})$	0.036	0.016	0.012	0.009	0.006
I	Trans cost per MWh curtailed savings (\$/MWh)	$B/(G(\text{initial})-G)$		\$ 46.1	\$ 42.7	\$ 55.7	\$ 79.4



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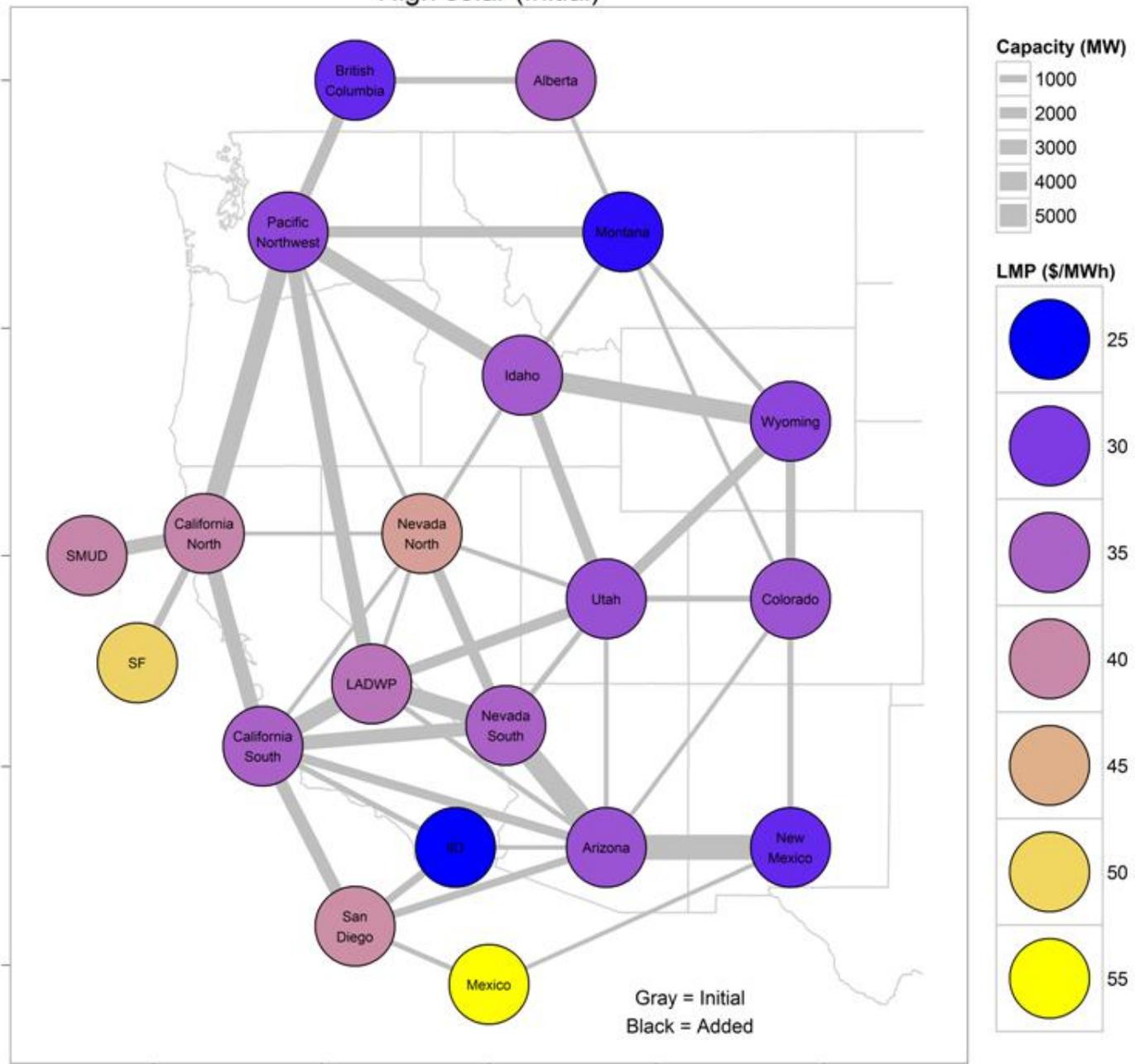
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**Base Case**

**High solar scenario**

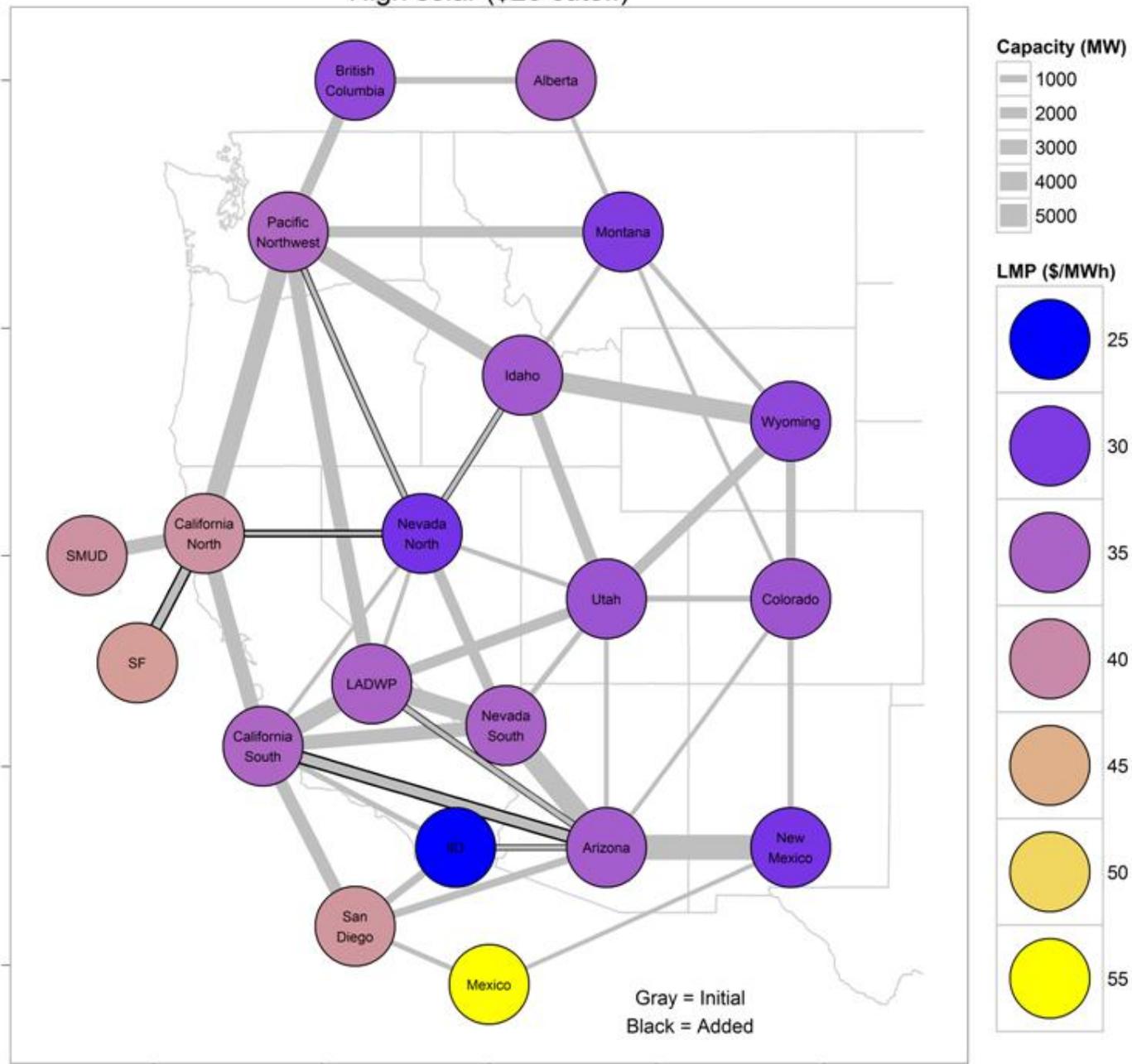


### High solar (Initial)



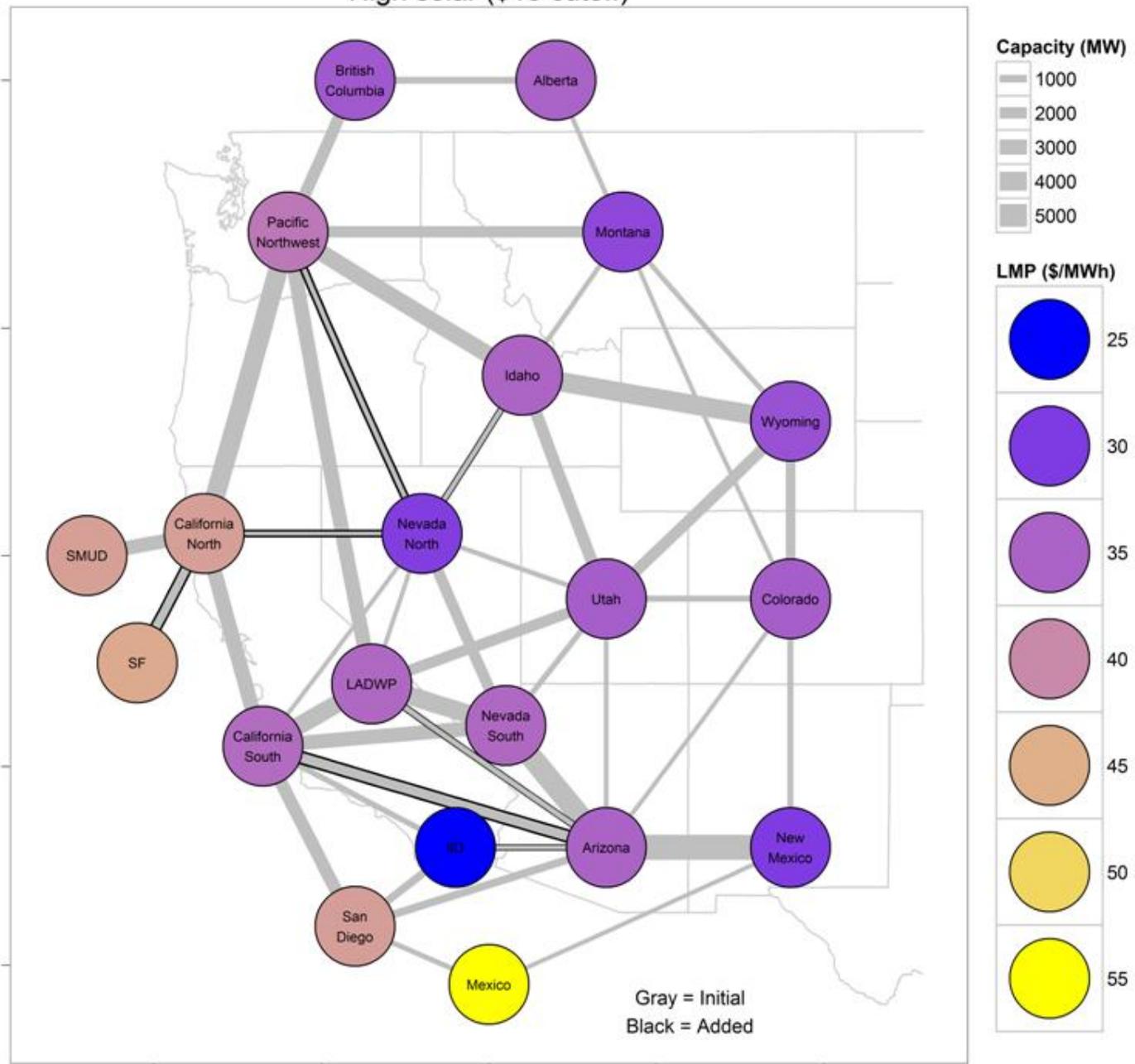


### High solar (\$20 cutoff)



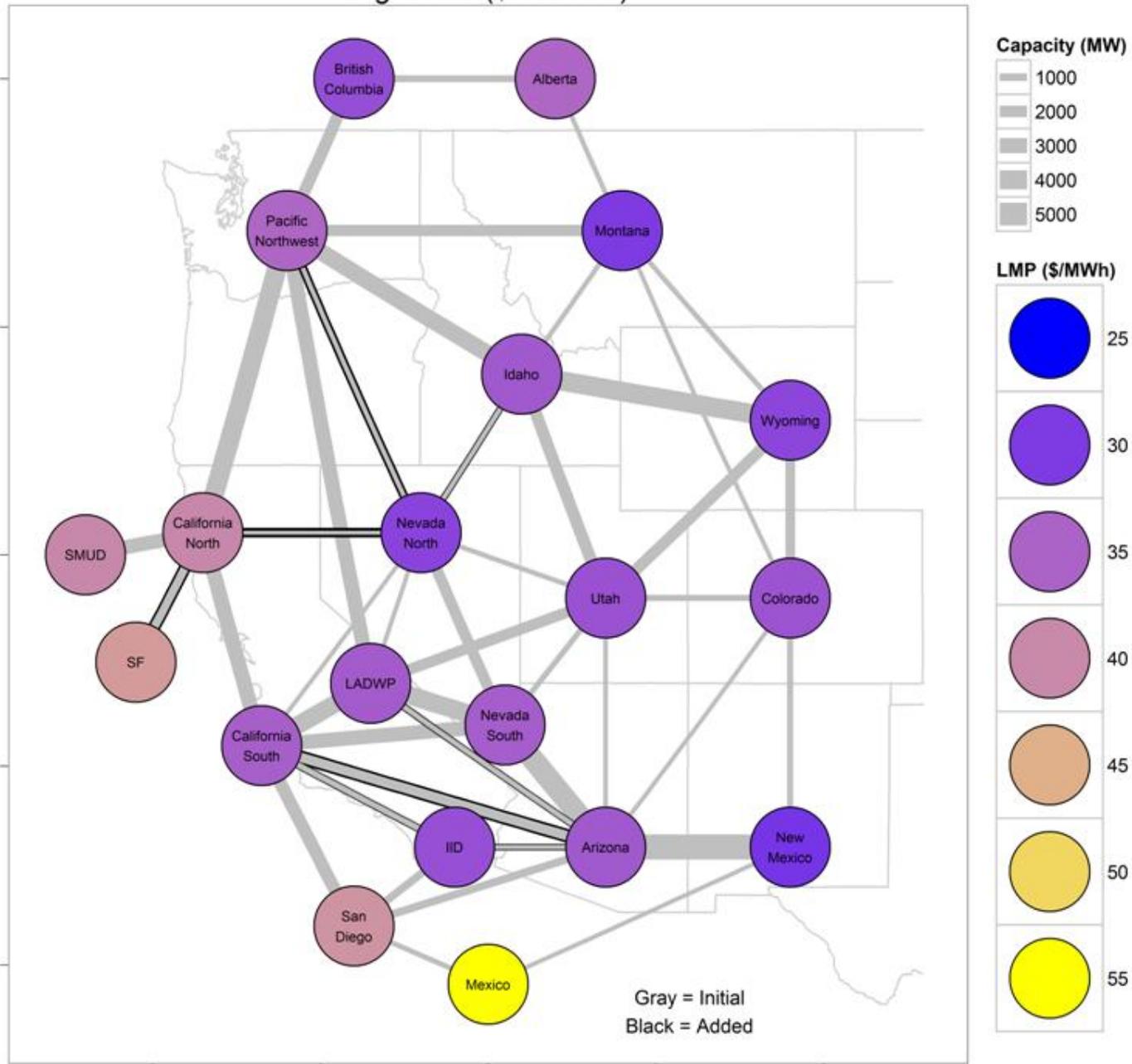


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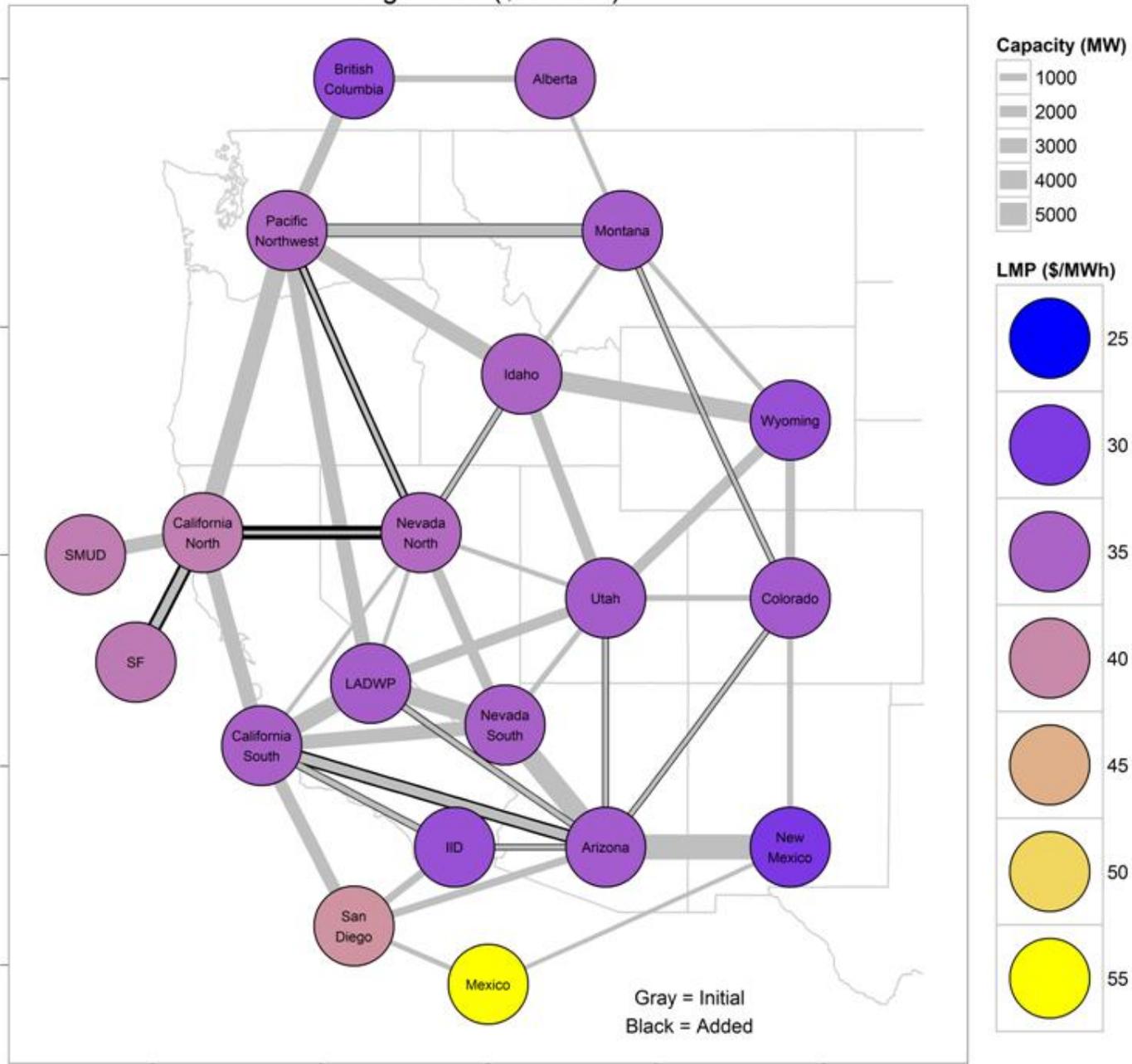


### High solar (\$10 cutoff)





### High solar (\$5 cutoff)





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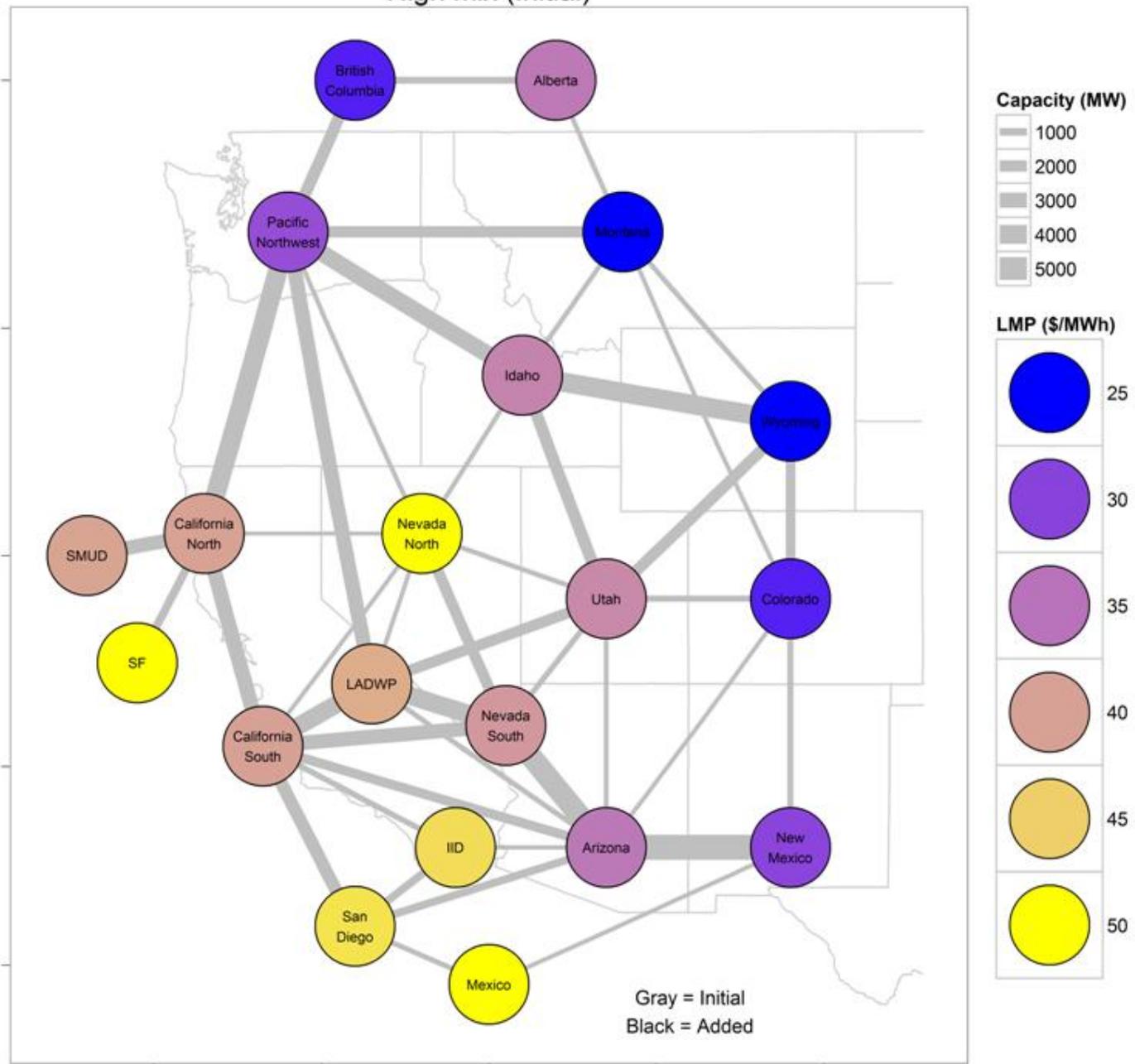
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**Base Case**

**High solar scenario**

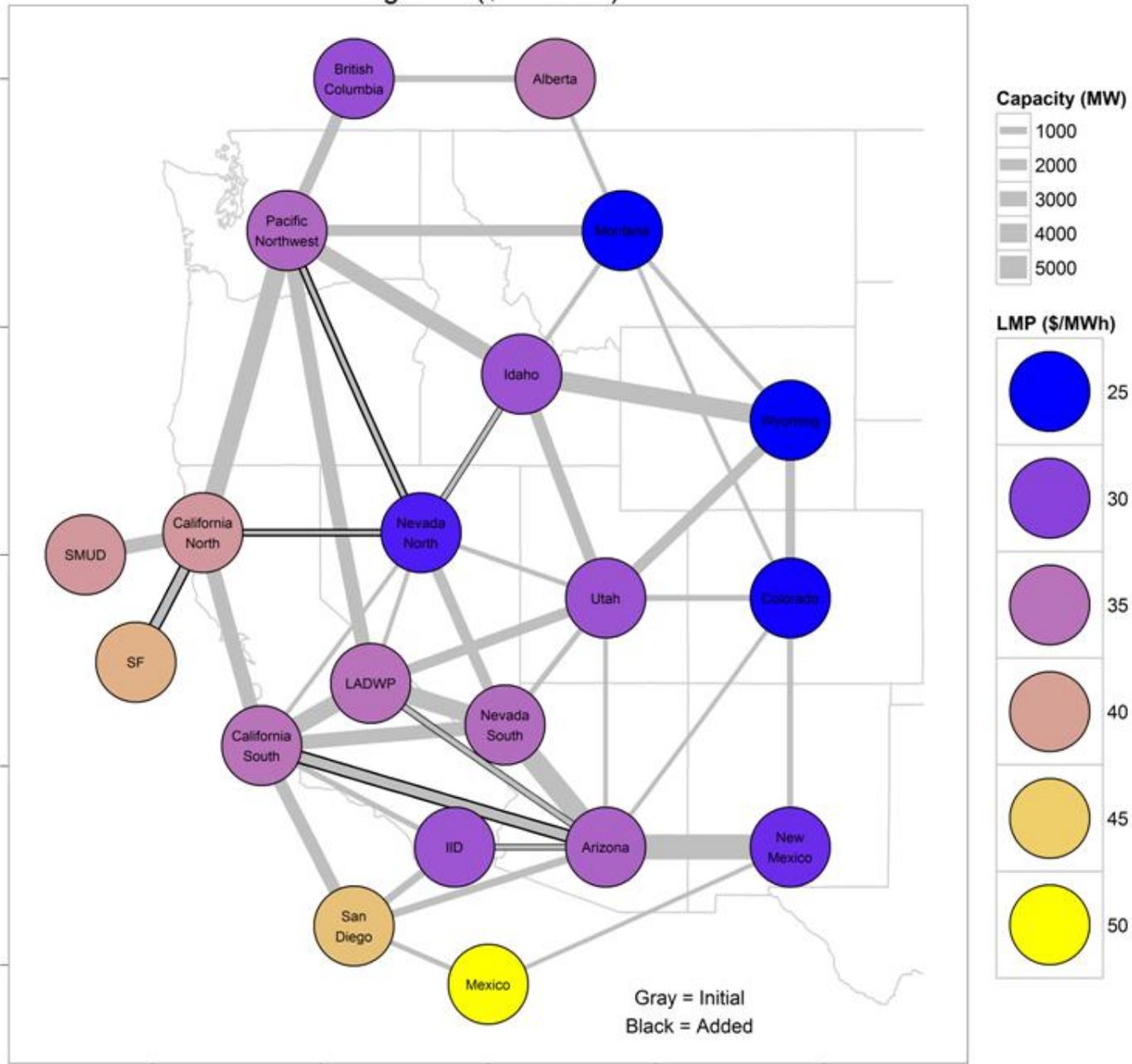


### High mix (Initial)



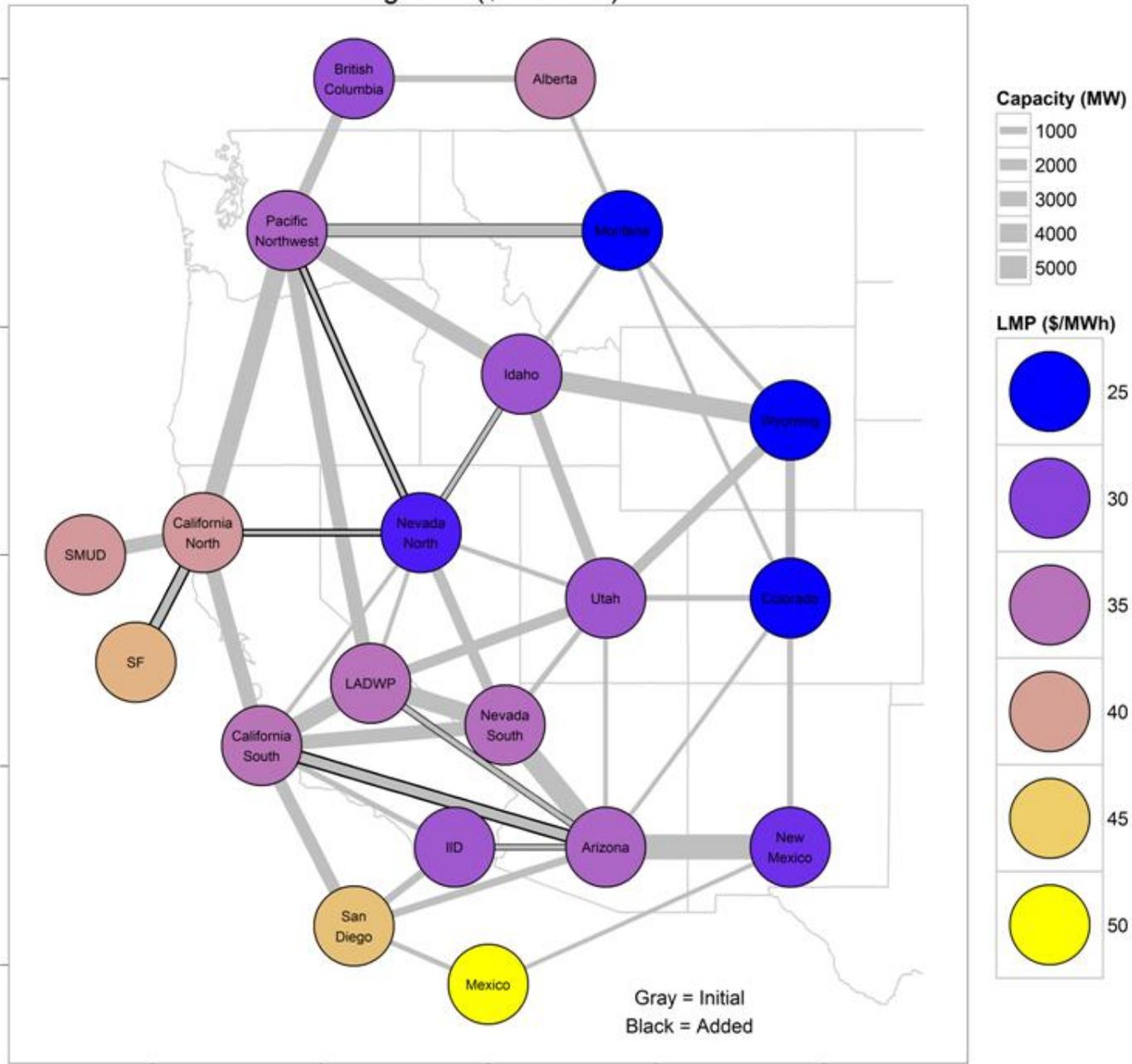


### High mix (\$20 cutoff)



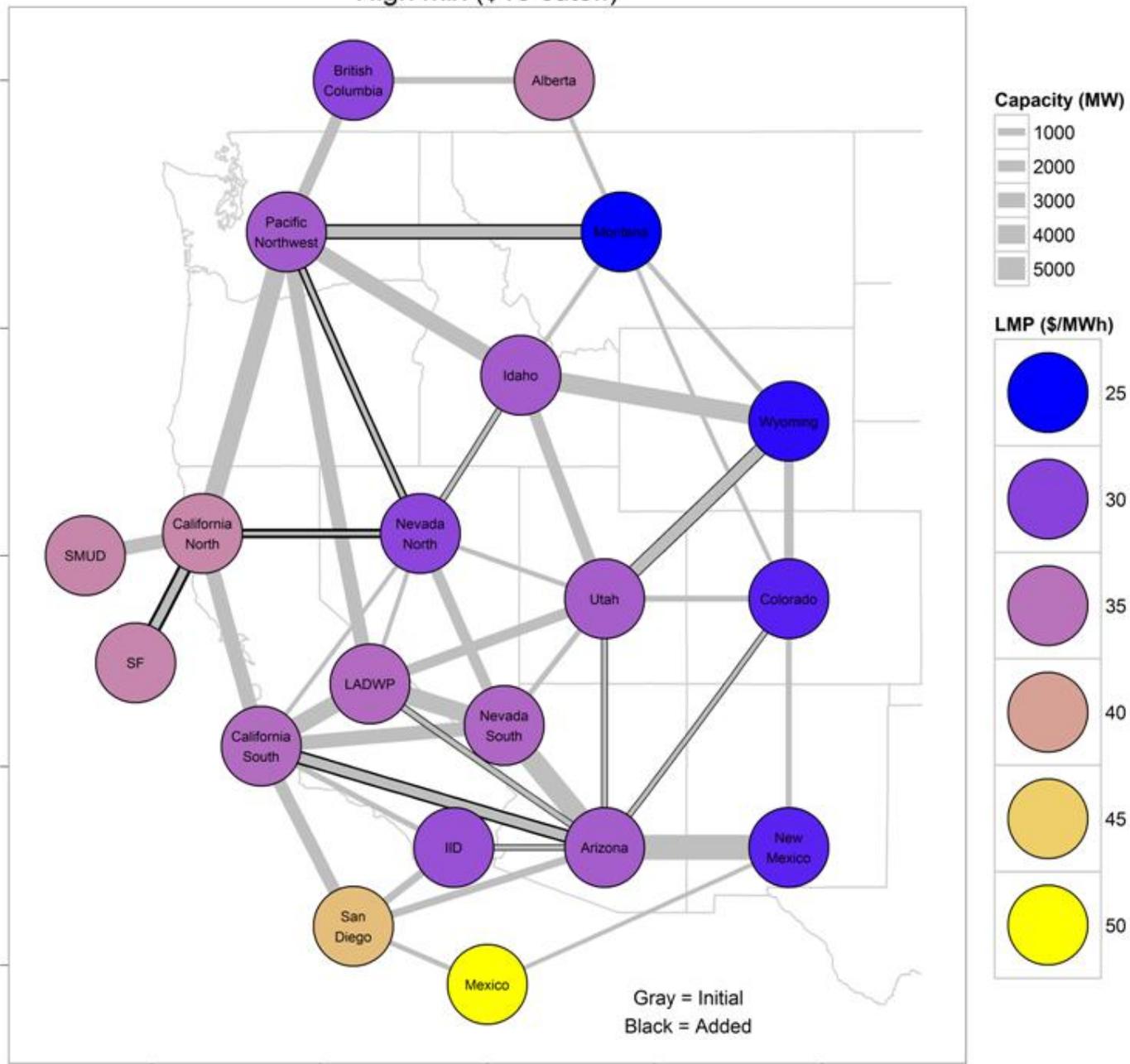


### High mix (\$15 cutoff)



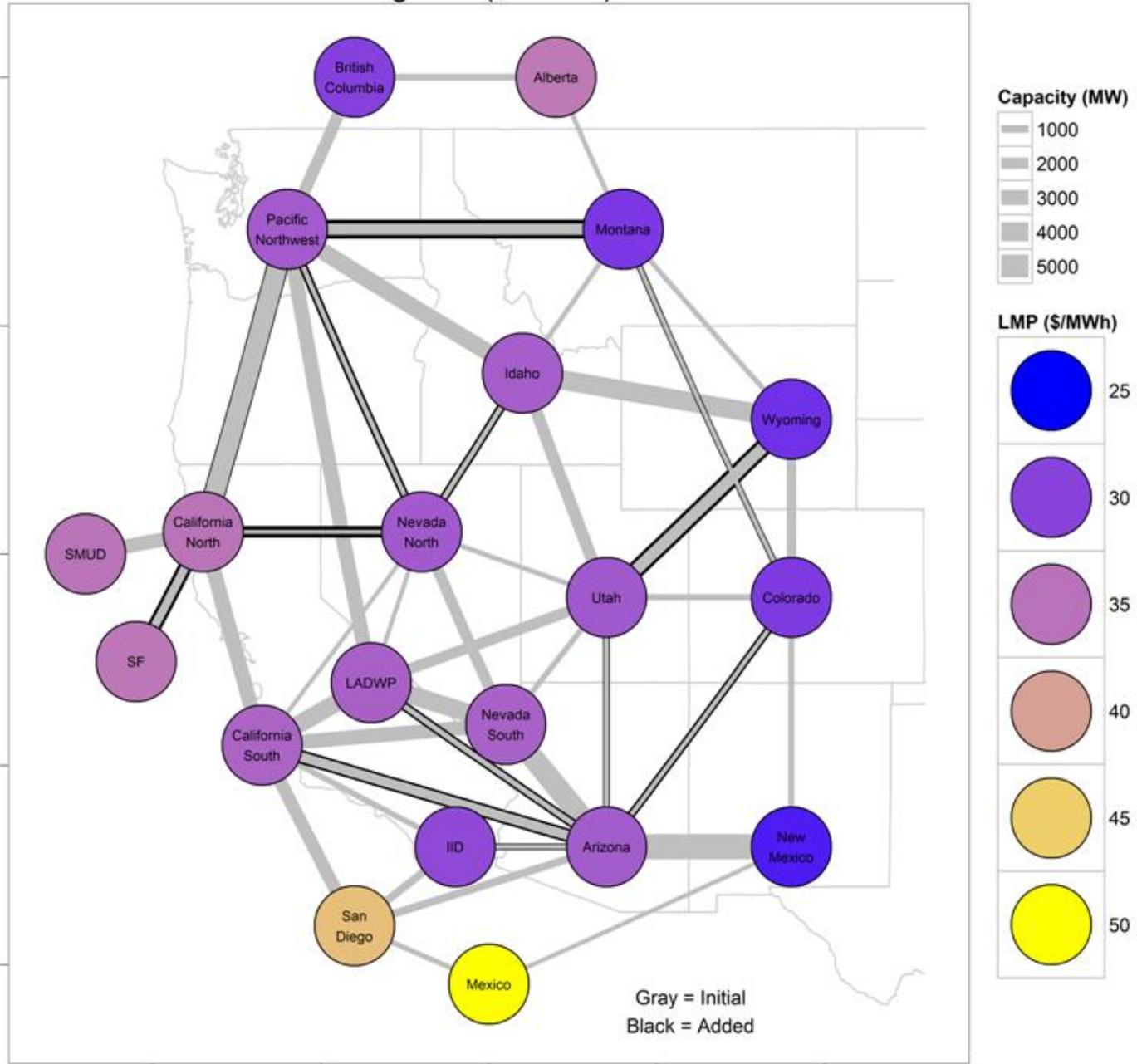


### High mix (\$10 cutoff)





### High mix (\$5 cutoff)





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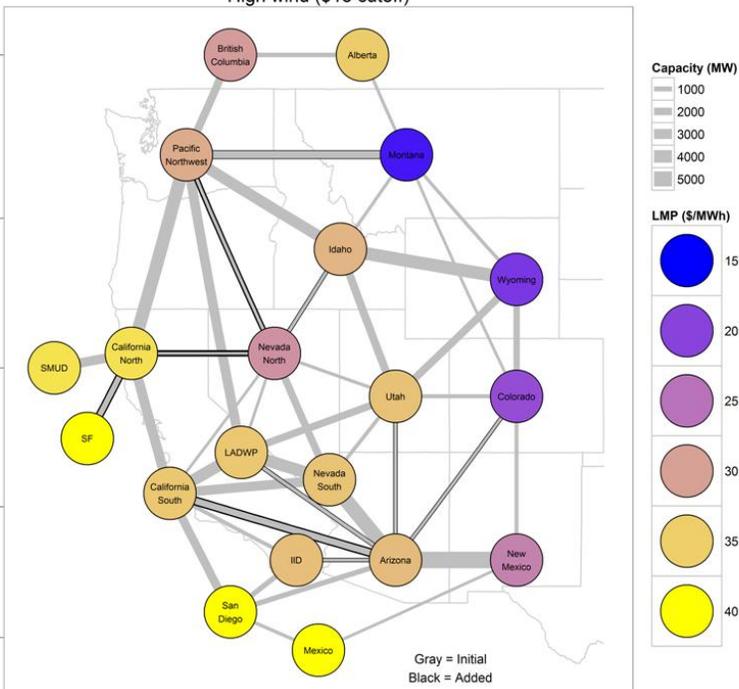
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Base Case

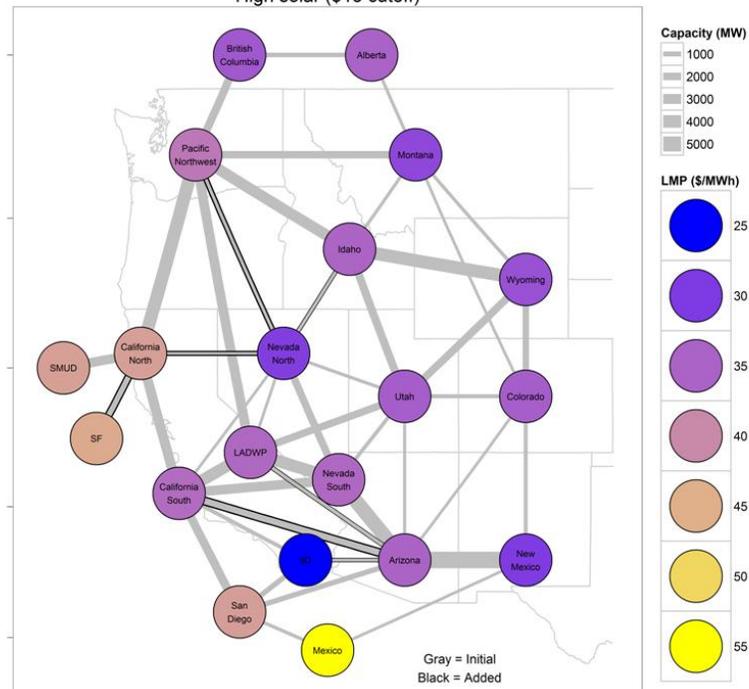
Comparisons

01

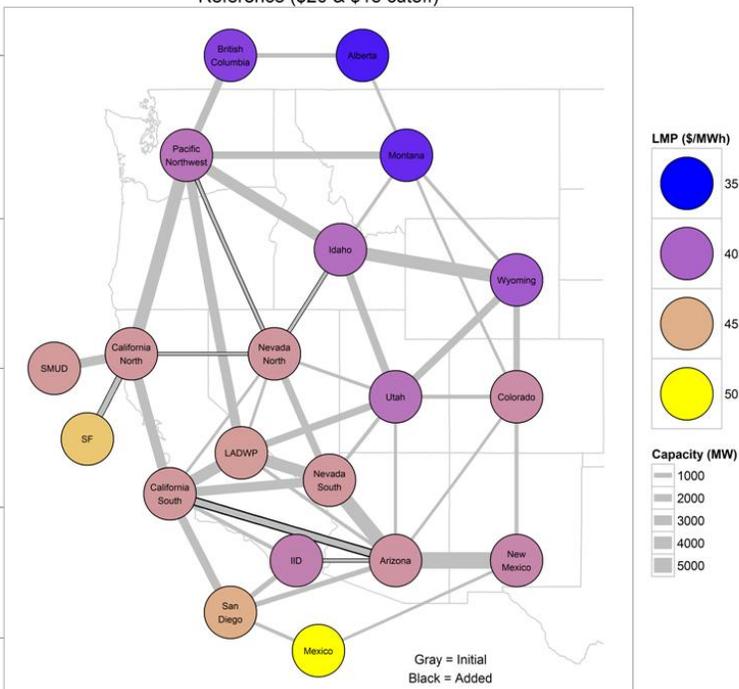
High wind (\$15 cutoff)



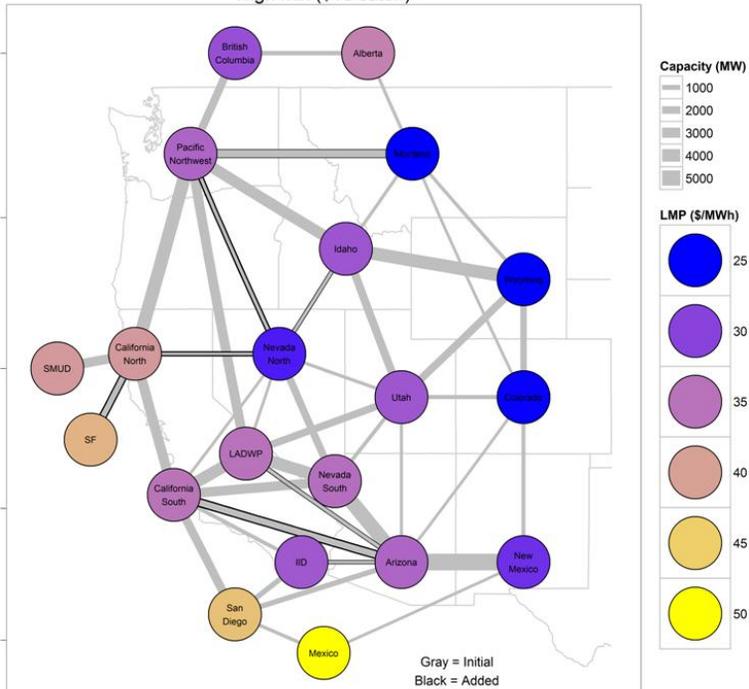
High solar (\$15 cutoff)

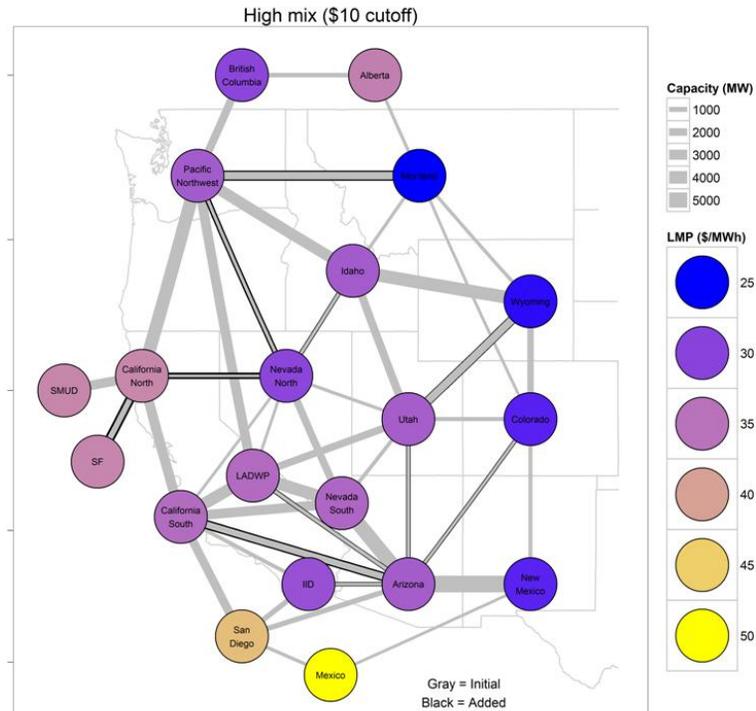
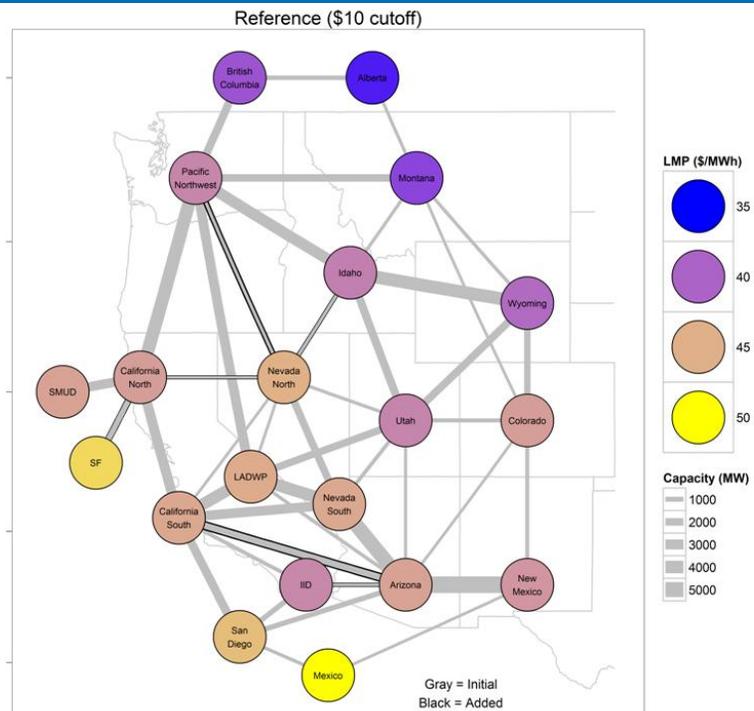
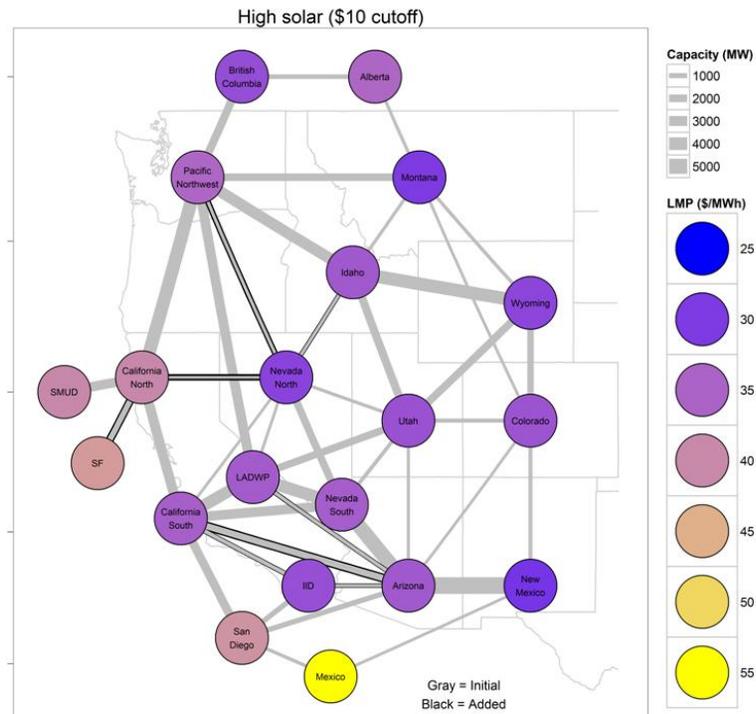
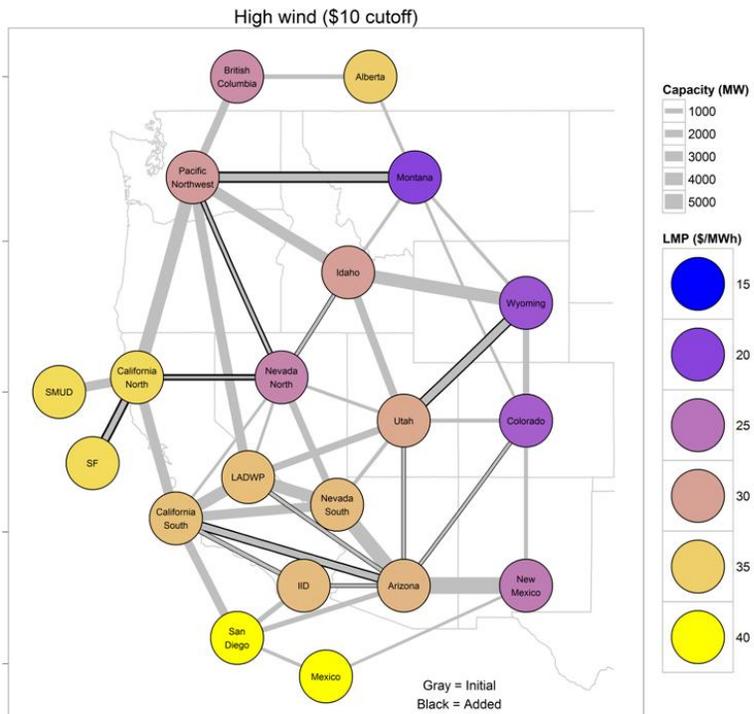


Reference (\$20 & \$15 cutoff)



High mix (\$15 cutoff)





	Initial	High wind				High solar				High mix				Reference		
		\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff	\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff	\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff	\$20/\$15 cutoff	\$10 cutoff	\$5 cutoff
Alberta to British Columbia	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alberta to Montana	325	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona to California_South	1600	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Arizona to Colorado	200	0	500	500	1500	0	0	0	500	0	0	500	1000	0	0	500
Arizona to IID	195	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Arizona to LDWP	468	500	500	500	500	500	500	500	500	500	500	500	1000	0	0	0
Arizona to Nevada_South	4785	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona to New Mexico	5582	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona to San Diego	1168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona to Utah	250	0	500	500	500	0	0	0	500	0	0	500	500	0	0	500
British Columbia to Northwest	2200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_North to California_South	3000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_North to Nevada_North	100	1000	1500	1500	2500	1000	1000	1500	2500	1000	1000	1500	2000	500	500	1000
California_North to Northwest	4200	0	0	0	1000	0	0	0	0	0	0	0	500	0	0	0
California_North to San Francisco	1272	1000	1000	1500	1500	1000	1000	1000	1500	1000	1000	1500	1500	500	500	1000
California_North to SMUD	2750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_South to IID	600	0	0	500	500	0	0	500	500	0	0	0	0	0	0	500
California_South to LDWP	3750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_South to Nevada_North	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_South to Nevada_South	2814	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_South to San Diego	2440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado to Montana	200	0	0	0	500	0	0	0	500	0	0	0	500	0	0	500
Colorado to New Mexico	664	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado to Utah	650	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado to Wyoming	1595	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho to Montana	325	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho to Nevada_North	350	500	500	500	1000	500	500	500	500	500	500	500	1000	500	500	500
Idaho to Northwest	3400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho to Utah	2250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho to Wyoming	4100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IID to San Diego	1150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LDWP to Nevada_North	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LDWP to Nevada_South	3883	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LDWP to Northwest	2858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LDWP to Utah	1920	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mexico (CFE) to New Mexico	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mexico (CFE) to San Diego	408	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montana to Northwest	2000	0	500	1500	3000	0	0	0	500	0	500	1000	2000	0	0	0
Montana to Wyoming	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nevada_North to Nevada_South	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nevada_North to Northwest	300	1000	1000	1000	1000	500	1000	1000	1000	1000	1000	1000	1000	500	1000	1000
Nevada_North to Utah	360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nevada_South to Utah	600	0	0	0	500	0	0	0	0	0	0	0	0	0	0	0
Utah to Wyoming	2100	0	0	1000	2500	0	0	0	0	0	0	500	1500	0	0	0

	Initial	\$20 cutoff				\$15 cutoff				\$10 cutoff				\$5 cutoff			
		High wind	High solar	High mix	Reference	High wind	High solar	High mix	Reference	High wind	High solar	High mix	Reference	High wind	High solar	High mix	Reference
Alberta to British Columbia	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alberta to Montana	325	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona to California_South	1600	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Arizona to Colorado	200	0	0	0	0	500	0	0	0	500	0	500	0	1500	500	1000	500
Arizona to IID	195	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Arizona to LDWP	468	500	500	500	0	500	500	500	0	500	500	500	0	500	500	1000	0
Arizona to Nevada_South	4785	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona to New Mexico	5582	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona to San Diego	1168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arizona to Utah	250	0	0	0	0	500	0	0	0	500	0	500	0	500	500	500	500
British Columbia to Northwest	2200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_North to California_South	3000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_North to Nevada_North	100	1000	1000	1000	500	1500	1000	1000	500	1500	1500	1500	500	2500	2500	2000	1000
California_North to Northwest	4200	0	0	0	0	0	0	0	0	0	0	0	0	1000	0	500	0
California_North to San Francisco	1272	1000	1000	1000	500	1000	1000	1000	500	1500	1000	1500	500	1500	1500	1500	1000
California_North to SMUD	2750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_South to IID	600	0	0	0	0	0	0	0	0	500	500	0	0	500	500	0	500
California_South to LDWP	3750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_South to Nevada_North	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_South to Nevada_South	2814	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
California_South to San Diego	2440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado to Montana	200	0	0	0	0	0	0	0	0	0	0	0	0	500	500	500	500
Colorado to New Mexico	664	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado to Utah	650	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colorado to Wyoming	1595	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho to Montana	325	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho to Nevada_North	350	500	500	500	500	500	500	500	500	500	500	500	500	1000	500	1000	500
Idaho to Northwest	3400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho to Utah	2250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho to Wyoming	4100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IID to San Diego	1150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LDWP to Nevada_North	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LDWP to Nevada_South	3883	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LDWP to Northwest	2858	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LDWP to Utah	1920	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mexico (CFE) to New Mexico	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mexico (CFE) to San Diego	408	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montana to Northwest	2000	0	0	0	0	500	0	500	0	1500	0	1000	0	3000	500	2000	0
Montana to Wyoming	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nevada_North to Nevada_South	2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nevada_North to Northwest	300	1000	500	1000	500	1000	1000	1000	500	1000	1000	1000	1000	1000	1000	1000	1000
Nevada_North to Utah	360	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nevada_South to Utah	600	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0
Utah to Wyoming	2100	0	0	0	0	0	0	0	0	1000	0	500	0	2500	0	1500	0

	Initial	High wind				High solar				High mix				Reference			
		\$20 cut	\$15 cut	\$10 cut	\$5 cut	\$20 cut	\$15 cut	\$10 cut	\$5 cut	\$20 cut	\$15 cut	\$10 cut	\$5 cut	\$20/\$15 cut	\$10 cut	\$5 cut	
Arizona to California_South	1600	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Arizona to Colorado	200	0	500	500	1500	0	0	0	500	0	0	500	1000	0	0	500	
Arizona to IID	195	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	
Arizona to LDWP	468	500	500	500	500	500	500	500	500	500	500	500	1000	0	0	0	
Arizona to Utah	250	0	500	500	500	0	0	0	500	0	0	500	500	0	0	500	
California_North to Nevada_North	100	1000	1500	1500	2500	1000	1000	1500	2500	1000	1000	1500	2000	500	500	1000	
California_North to Northwest	4200	0	0	0	1000	0	0	0	0	0	0	0	500	0	0	0	
California_North to San Francisco	1272	1000	1000	1500	1500	1000	1000	1000	1500	1000	1000	1500	1500	500	500	1000	
California_South to IID	600	0	0	500	500	0	0	500	500	0	0	0	0	0	0	500	
Colorado to Montana	200	0	0	0	500	0	0	0	500	0	0	0	500	0	0	500	
Idaho to Nevada_North	350	500	500	500	1000	500	500	500	500	500	500	500	1000	500	500	500	
Montana to Northwest	2000	0	500	1500	3000	0	0	0	500	0	500	1000	2000	0	0	0	
Nevada_North to Northwest	300	1000	1000	1000	1000	500	1000	1000	1000	1000	1000	1000	1000	500	1000	1000	
Nevada_South to Utah	600	0	0	0	500	0	0	0	0	0	0	0	0	0	0	0	
Utah to Wyoming	2100	0	0	1000	2500	0	0	0	0	0	0	500	1500	0	0	0	

		High wind				High solar				High mix				Reference		
	Initial	\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff	\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff	\$20 cutoff	\$15 cutoff	\$10 cutoff	\$5 cutoff	\$20/\$15 cutoff	\$10 cutoff	\$5 cutoff
Arizona to California_South	1600	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Arizona to Colorado	200	0	500	500	1500	0	0	0	500	0	0	500	1000	0	0	500
Arizona to IID	195	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Arizona to LDWP	468	500	500	500	500	500	500	500	500	500	500	500	1000	0	0	0
Arizona to Utah	250	0	500	500	500	0	0	0	500	0	0	500	500	0	0	500
California_North to Nevada_North	100	1000	1500	1500	2500	1000	1000	1500	2500	1000	1000	1500	2000	500	500	1000
California_North to Northwest	4200	0	0	0	1000	0	0	0	0	0	0	0	500	0	0	0
California_North to San Francisco	1272	1000	1000	1500	1500	1000	1000	1000	1500	1000	1000	1500	1500	500	500	1000
California_South to IID	600	0	0	500	500	0	0	500	500	0	0	0	0	0	0	500
Colorado to Montana	200	0	0	0	500	0	0	0	500	0	0	0	500	0	0	500
Idaho to Nevada_North	350	500	500	500	1000	500	500	500	500	500	500	500	1000	500	500	500
Montana to Northwest	2000	0	500	1500	3000	0	0	0	500	0	500	1000	2000	0	0	0
Nevada_North to Northwest	300	1000	1000	1000	1000	500	1000	1000	1000	1000	1000	1000	1000	500	1000	1000
Nevada_South to Utah	600	0	0	0	500	0	0	0	0	0	0	0	0	0	0	0
Utah to Wyoming	2100	0	0	1000	2500	0	0	0	0	0	0	500	1500	0	0	0

# Questions?

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# Extra slides for addressing potential questions

# Renewable generation profiles

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## Solar

- Remake all solar generation data, down to 1-min resolution
- PV is 60% of solar, CSP is 40%

Distribution to regions based on the ReEDS results

Distribution within regions based on the following rules:

- Rooftop PV is 40% of PV where possible
  - Capacity distributed by population (same capacity per person)
  - Maximum capacity per grid cell of 1 kW/person
  - All scenarios use same sites with different capacity per grid cell
- Distributed utility PV is ~20% of PV
  - Sited near population areas
  - Scenarios use subset of sites
- “Remote-site” utility PV is 40% of PV
  - Sited based on capacity factor
  - Scenarios use subset of sites

# Renewable generation profiles

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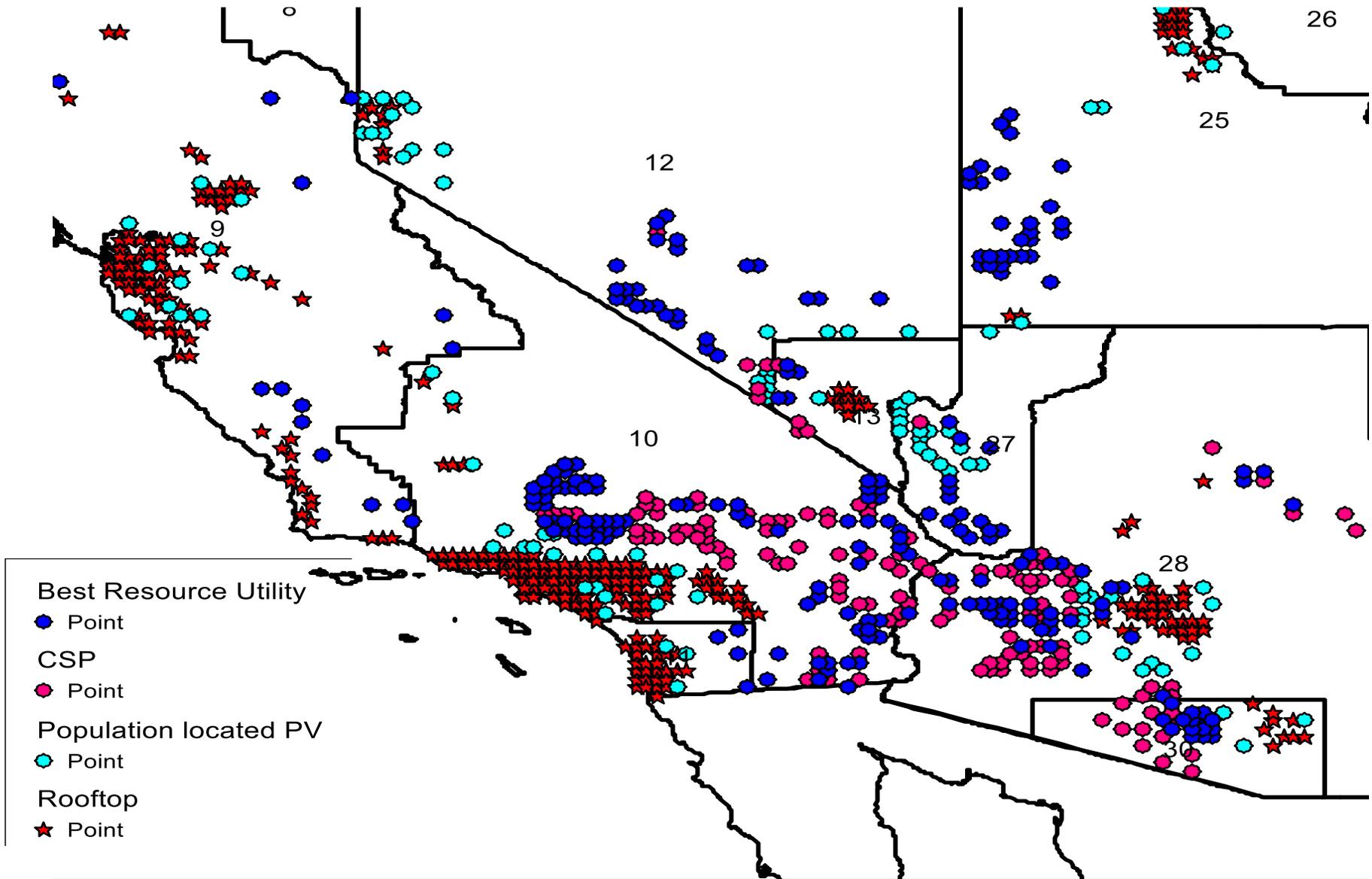
## Wind

- Sited by capacity factor within ReEDS region
- Close capacity factor sites were sometimes substituted so not all wind was in same location
- Use WWSIS phase 1 data set
- Statistically downsampled data available for subhourly analysis

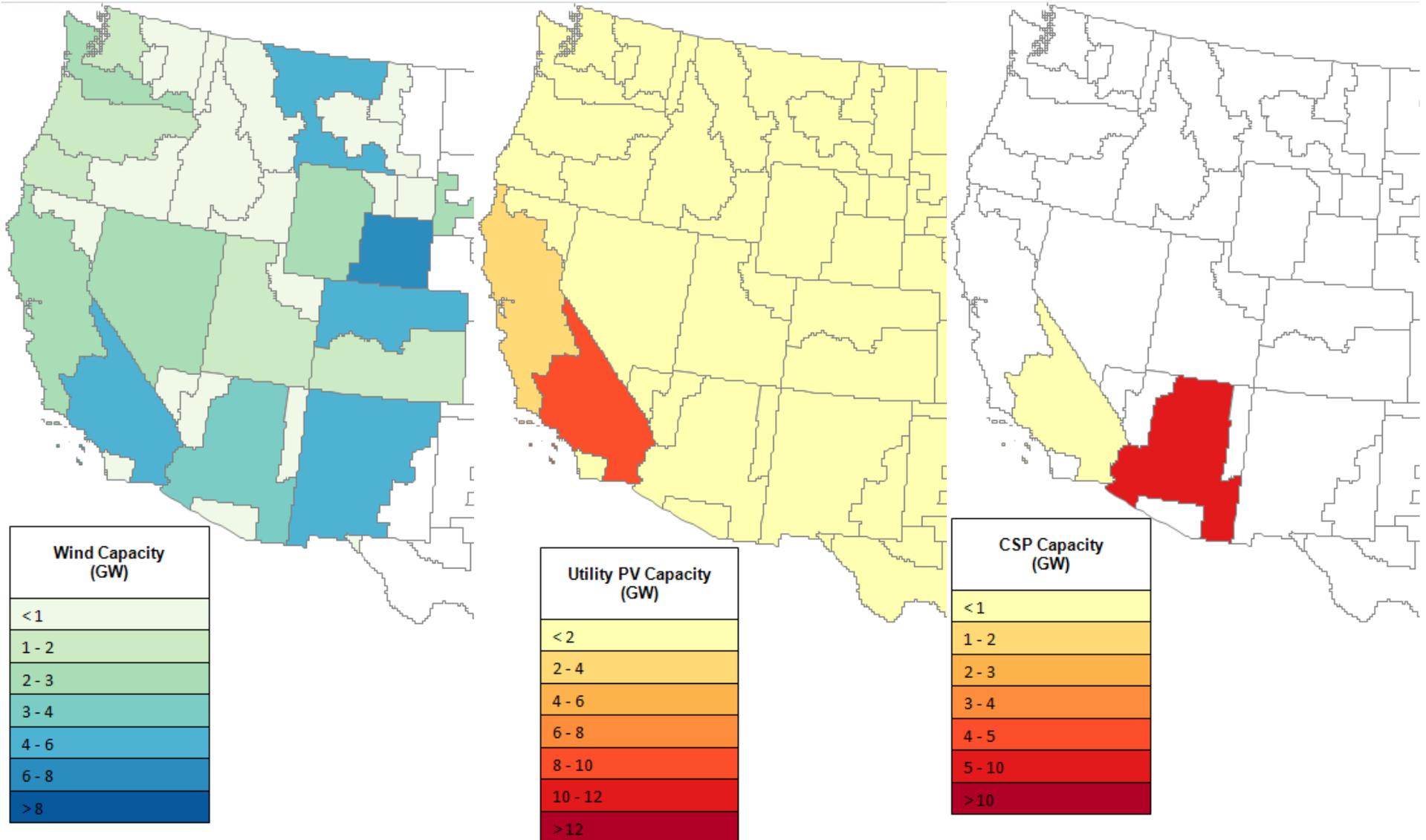
## Load

- 2006 1-min data available from WECC VGS
- 2004 or 2005?

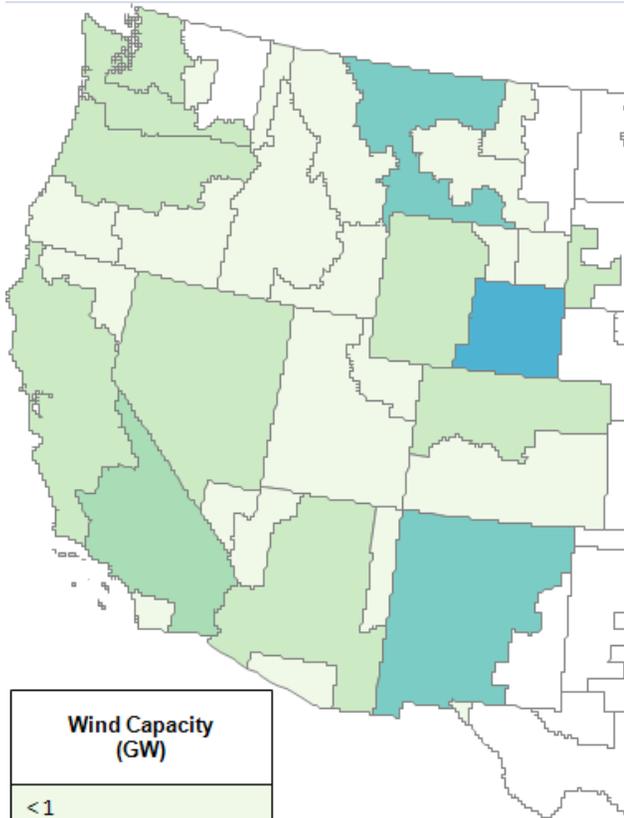
# Sample map of solar sites



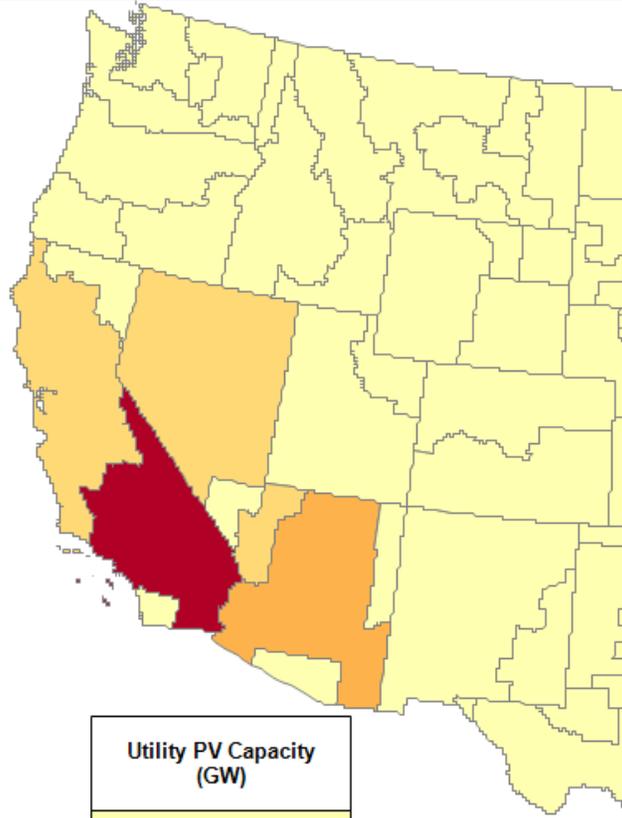
# High wind (25% wind, 4.8% PV, 3.2% CSP)



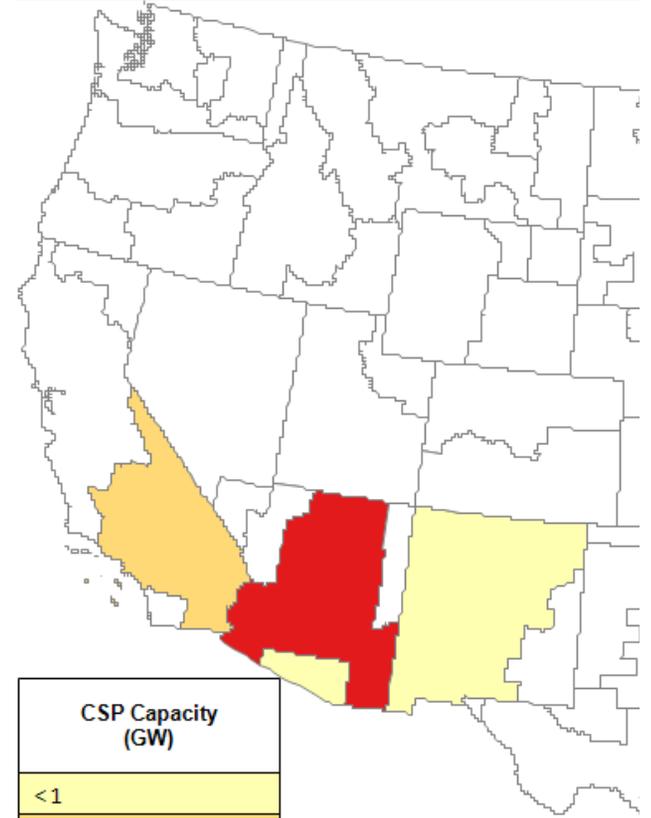
# Intermediate (16.5% wind, 9.9% PV, 6.6% CSP)



Wind Capacity (GW)
< 1
1 - 2
2 - 3
3 - 4
4 - 6
6 - 8
> 8

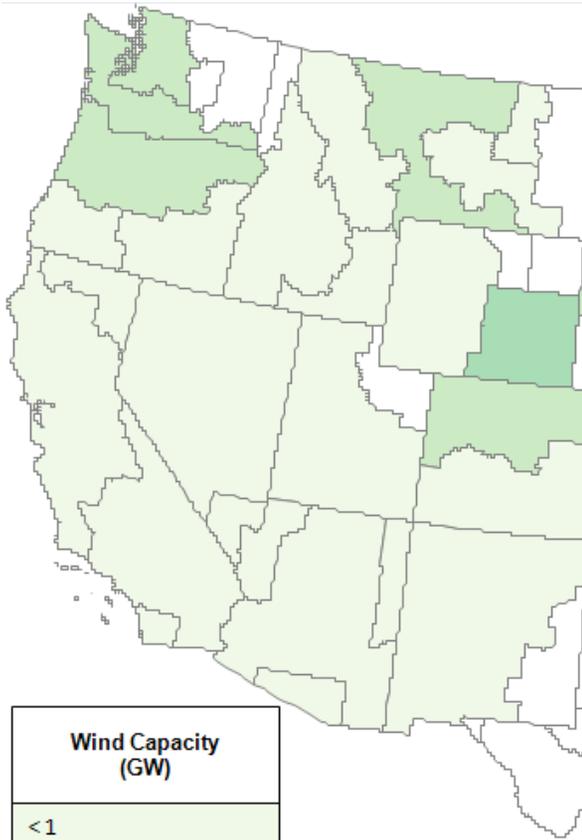


Utility PV Capacity (GW)
< 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
> 12

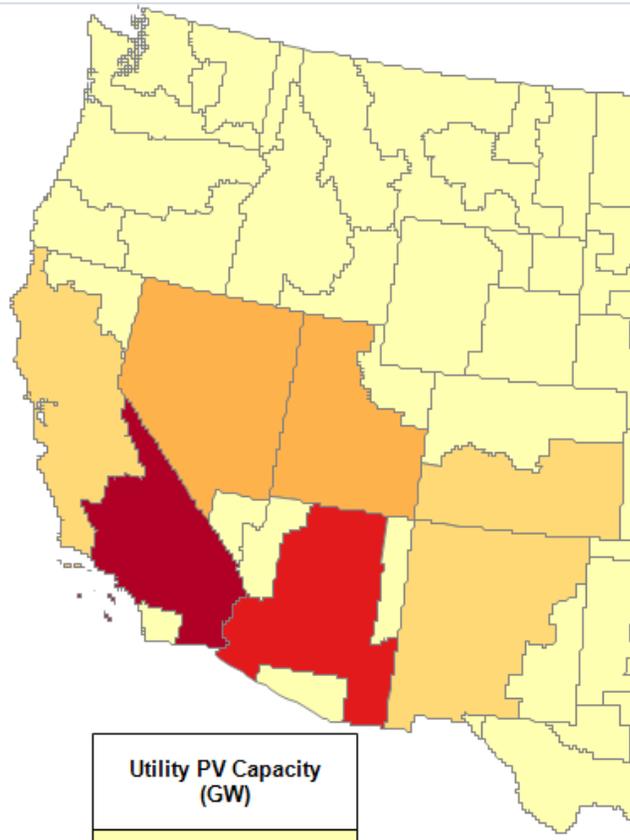


CSP Capacity (GW)
< 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 10
> 10

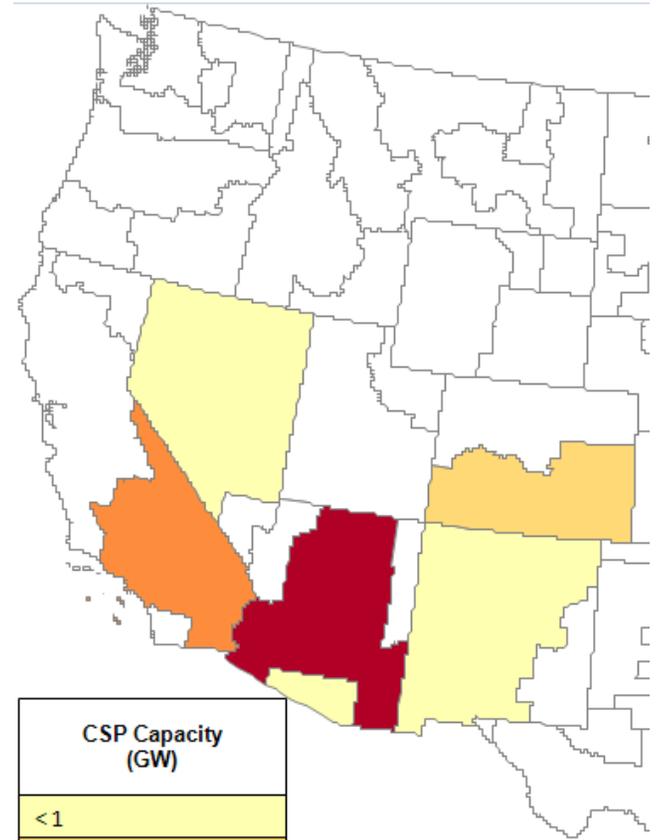
# High solar (8% wind, 15% PV, 10% CSP)



Wind Capacity (GW)
< 1
1 - 2
2 - 3
3 - 4
4 - 6
6 - 8
> 8



Utility PV Capacity (GW)
< 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
> 12



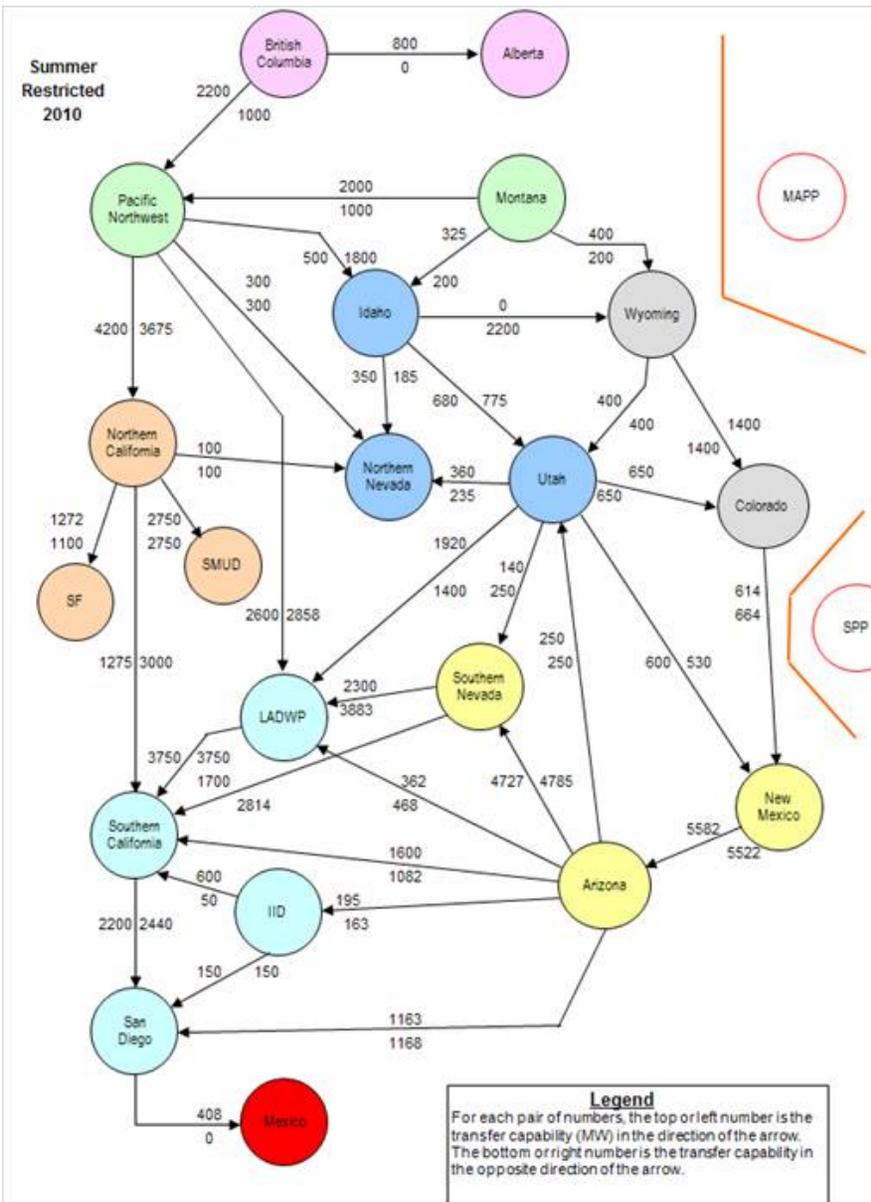
CSP Capacity (GW)
< 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 10
> 10

# Retirement Scenarios

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- All scenarios (including base case TEPPC 2020)
  - Probably use WECC TEPPC DWG projections
  - May need to add capacity if additional units are retired from TEPPC 2020 case
    - Gas CC added in locations where capacity is retired
- Sensitivity analysis on additional retirements for renewable scenarios
  - Amount retired will be based on capacity value of renewables

# Transmission zones



- Run zonally initially. Nodal runs at a later date for deeper dives.
- Propose to use these 20 TEPPC zones. Aiming at more rather than less zones to better approximate actual current operations.
- Commit and dispatch within each zone with no hurdle rates between zones to allow for interzone transfers.

# Capacity (GW) by state for 3 scenarios

	HighWind			Intermediate			HighSolar		
	Wind	PV	CSP	Wind	PV	CSP	Wind	PV	CSP
AZ	4.3	4.8	4.0	1.4	9.5	9.5	0.2	14.5	9.7
CA	11.1	11.6	3.0	5.9	16.1	3.8	5.4	19.4	9.2
CO	5.5	2.5	0.2	3.9	2.6	0.2	3.0	5.1	1.3
ID	1.1	0.0	0.0	1.0	0.0	0.0	0.5	0.0	0.0
MT	5.9	0.1	0.0	4.0	0.1	0.0	1.0	0.1	0.0
NM	4.2	0.4	0.1	2.8	2.1	0.3	0.5	3.2	0.6
NV	2.8	0.9	0.6	1.4	4.1	0.6	0.2	6.6	0.6
OR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SD	2.3	0.0	0.0	1.9	0.0	0.0	0.3	0.0	0.0
TX	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.5	0.0
UT	1.1	0.9	0.0	0.6	2.2	0.0	0.3	4.9	0.0
WA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WY	9.0	0.0	0.0	6.8	0.0	0.0	1.5	0.0	0.0
Total	47.3	21.3	7.8	29.6	37.1	14.4	13.0	54.2	21.3